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SORGHUM DISEASES
and their control

FARMERS' BULLETIN NO. 1959
U. S. DEPARTMENT OF AGRICULTURE

Good stands and yields of sorghums—
the leading feed crop in many parts of the country—
can be obtained by disease prevention and control

SORGHUMS ARE INJURED BY—

Seed rots and seedling blights—

causing poor stands.

Leaf diseases—

destroying foliage and impairing grain development.

Smuts—

destroying the grain and stunting the plant.

Root rots—

destroying all or parts of many crops.

Stalk rots—

checking grain development, causing serious lodging, and reducing sirup production.

MANY DISEASES CAN BE PREVENTED OR CONTROLLED BY—

Growing disease-resistant varieties—

To prevent pythium root rot (*milo disease*)—one of the milo-type combine grain sorghums:

Westland	Double Dwarf Yellow 38	Martin's Wheatland
Plainsman	Finney	Resistant Wheatland
Caprock	Texas	Resistant Beaver

To prevent certain leaf diseases—Tift and Sweet Sudan grass and Atlas and Leoti sorgo.

To control charcoal rot—Atlas sorgo and most varieties of kafir.

Using good seed—carefully selected, dry, sound, and free from thresher injury to the seed coat.

Treating the seed—with a good dust fungicide.

Planting seed in warm mellow soil—cold, wet, heavy soil causes poor stands.

Washington, D. C. Issued October 1944

SORGHUM DISEASES AND THEIR CONTROL

By R. W. LEUKEL, *pathologist*, JOHN H. MARTIN, *senior agronomist, Division of Cereal Crops and Diseases*, and C. L. LEFEBVRE, *pathologist, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration*

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SORGHUM, a source of both grain and forage, is the chief feed crop in much of the Great Plains. It is important also in other sections of the country. In addition, grain sorghum is used in alcohol manufacture and in the brewing industry, and waxy varieties are made into a substitute for tapioca, which became unavailable for food purposes when World War II broke out, but is important not only for food but also in the manufacture of adhesives. Sorgo (sweet sorghum) furnishes hay, fodder, silage, and sirup and is a potential source of cane sugar.

Of the numerous diseases to which sorghum [1] is subject, some of which frequently cause heavy losses, four general types may be recognized: (1) Those that reduce stands by rotting the seed or by killing the seedlings; (2) those that attack the leaves and decrease the value of the plants for forage; (3) those that attack only the heads and prevent the normal formation of grain; and (4) those that cause root or stalk rots and prevent the normal development and maturity of the entire plant. The importance of sorghum as a source of feed and forage, sirup, material for making brooms, and a type of starch makes it desirable, particularly in time of war, that the different diseases be recognized and controlled as far as possible.

The varieties of sorghum grown in the United States fall into four more or less distinct groups: (1) Sorgos (sweet or saccharine sorghums, or so-called "cane"), grown for forage, silage, or sirup; (2) grain sorghums (including hegari, kafir, milo, shallu, and darso), grown mostly for grain but also for forage or silage; (3) broomcorn,

[1] *Sorghum vulgare* Pers.

grown for the brush fiber; and (4) grass sorghums (consisting of Sudan grass [2] and the related Johnson grass),[3] grown for forage.

In each of the four sorghum groups certain varieties may be resistant to one or more of the four types of disease. On the other hand, some diseases may damage one group more than another. Thus, the smuts, which destroy the seeds, cause a direct proportional reduction in the grain yield of grain sorghums, but in sorgo they reduce the yield of forage or sirup only slightly. In broomcorn, smut may not affect the yield of fiber but if it is abundant it blackens the brush and lowers its market value. The effect of smut on broomcorn seed production is slight, because less than 1 percent of the total broomcorn acreage is grown especially for seed and that usually is treated before being planted.

Leaf diseases cause relatively small reduction in the yield of grain sorghum, but they may seriously impair the production of forage from Sudan grass and sorgo in the Gulf and Atlantic Coastal Plains and other humid regions. Serious forage losses occur when the leaves dry up and break off the stalks, following severe disease attack. The red or purple coloration of the leaf and stem that follows a mild attack of some diseases usually has little influence on the yield or quality of grain or forage. On the other hand, the red stain stimulated in broomcorn brush by these diseases may reduce its market value one-half, as compared with bright-green but otherwise similar fiber. Also, the sirup produced from badly discolored stems of sorgo may have an undesirable dark color.

It is the purpose of this bulletin to describe the symptoms of the more important diseases of sorghum that occur in the United States and to recommend practicable control measures, in order to assist farmers in obtaining maximum production of this important crop.

SEED ROT AND SEEDLING DISEASES

Seed rot is most severe when the soil is cold and wet after planting. This condition is common in the North and also in other areas when seed is planted early. Under such conditions, much of the seed fails to germinate and rots because it is attacked by various seed-borne and soil-inhabiting fungi. These fungi are minute plants, similar to the common molds and mildews that get their food from other plants or plant material. To germinate promptly, sorghum seed requires a relatively warm soil (above 70° F.). Most seed-rotting fungi thrive at lower temperatures; consequently, low soil temperatures not only retard the germination of the seed but also give these harmful fungi ample opportunity to attack it. Some of the fungi [4] invade and destroy the endosperm, or starchy tissue of the seed, thus robbing it of the food necessary to produce a strong seedling. Cracks in the seed coats of the kernels give the fungi ready access to the interior and thus aggravate the trouble.

Some fungi, especially species of *Pythium*, attack the young sprout in its early stage of development and prevent it from emerging (fig. 1).

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[2] *Sorghum vulgare* var. *sudanense* (Piper) Hitchc.
[3] *Sorghum halepense* (L.) Pers.
[4] Chiefly species of *Fusarium, Aspergillus, Rhizopus, Rhizoctonia, Penicillium,* and *Helminthosporium.*

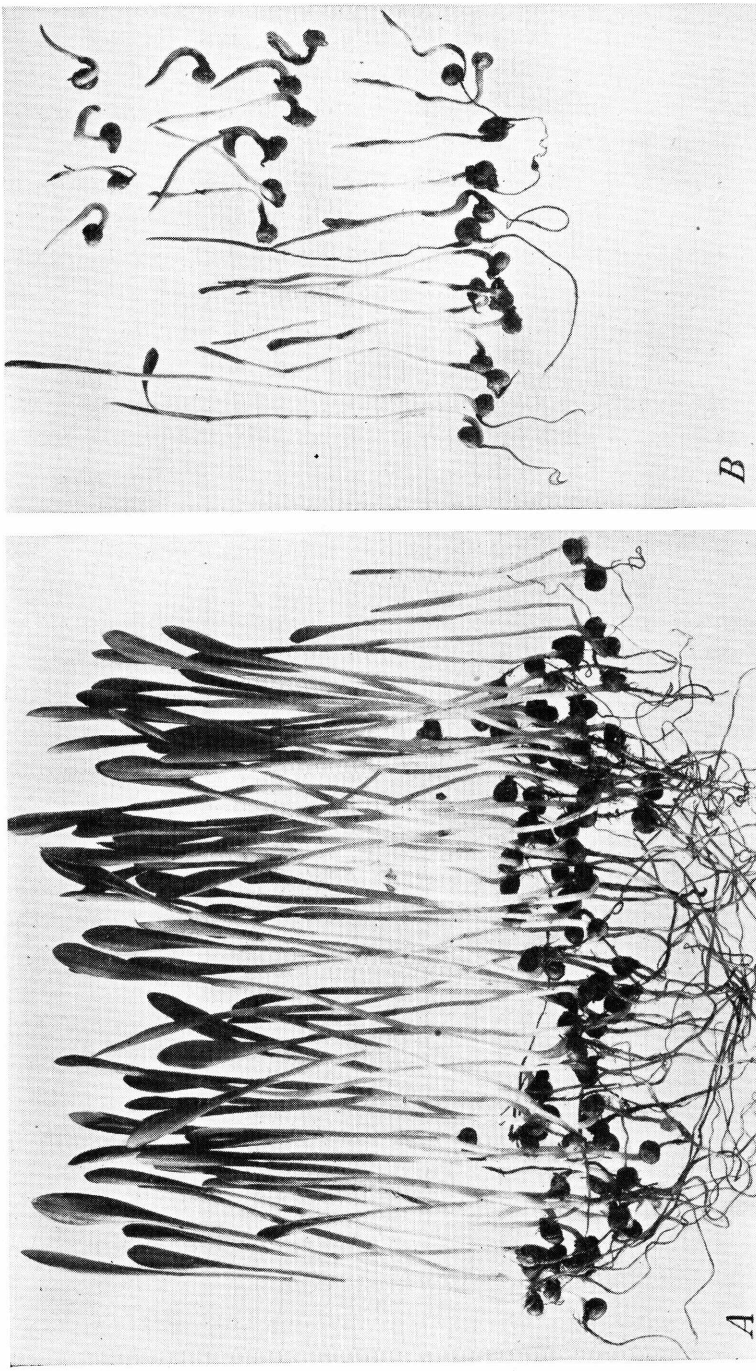

FIGURE 1.—Injury to Spur feterita seed and seedlings in pythium-infested soil at 68° F.: Seedlings from 100 seeds planted (*A*) in sterilized soil and (*B*) in pythium-infested soil. (Note poor germination, decayed roots and plumules, and arrested growth in infested soil.)

These fungi also attack and rot the primary roots, thus preventing the young seedlings from obtaining sufficient food materials from the soil to become well established. One species of *Fusarium*,[5] besides rotting the seed, frequently attacks sorghum seedlings at the surface of the soil soon after they have emerged and causes them to rot or damp off and fall over (fig. 2). This fungus may destroy the primary

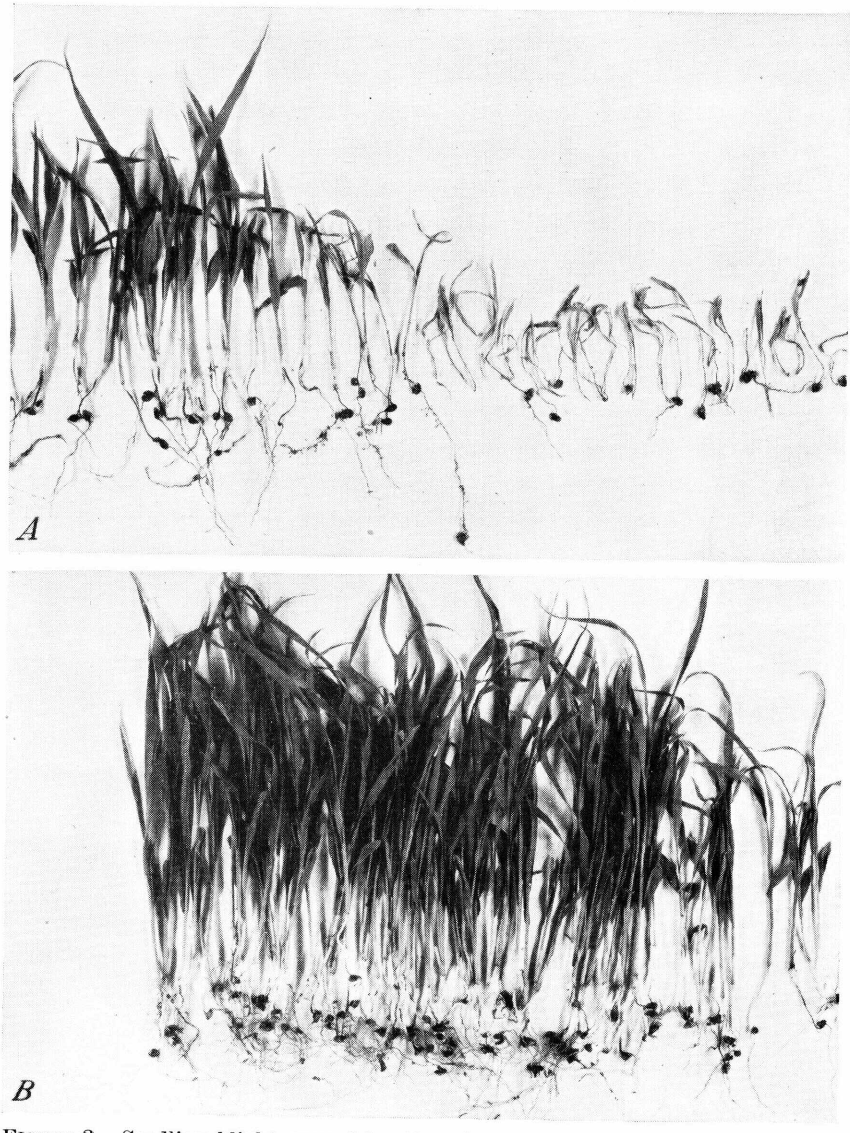

FIGURE 2.—Seedling blight caused by *Fusarium moniliforme* in sorghum plants grown at 68° F. in steamed soil (*A*) inoculated with the fungus; (*B*) not inoculated.

[5] *F. moniliforme* Sheldon = *Gibberella fujikuroi* (Saw.) Wr.

roots of young seedlings also. Some races of this fungus are more harmful than others. Another species of *Fusarium*[6] has been found capable of completely inhibiting germination in cold soil (below 65° F.). One species of *Penicillium*,[7] in addition to attacking the endosperm and thus arresting germination, may also kill the seedlings, even after they have reached the third- or fourth-leaf stage (fig. 3). This injury is characterized at the start by a grayish or silvery-green color of the leaves, followed by a gradual yellowing. The leaves become limp and curled and finally die. The plants do not fall over like those that damp off because of *Fusarium*, but remain upright even after they are dead. Seedlings attacked and killed by species of *Pythium* and *Helminthosporium* display similar symptoms and also remain erect.

Control measures.—Seed rot and seedling blight may be controlled to a considerable extent by careful selection and treatment of seed, along with proper cultural practices. Seed should be well matured

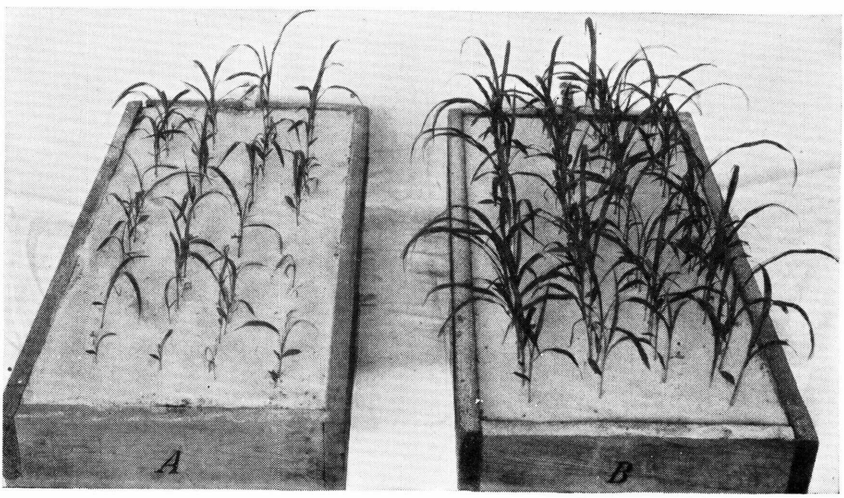

FIGURE 3.—Dwarf White milo grown in steamed soil: *A*, Inoculated with *Penicillium oxalicum*; *B*, not inoculated.

and properly cured, and the seed coat should be as free as possible from cracks and nicks, such as those that are often caused by improper adjustment of the threshing machine. Before being planted, the seed should be treated with a good dust disinfectant that will protect it not only from seed-borne fungi but also, to a great extent, from the harmful fungi present in the soil. (See page 42.) To insure good stands, the seed should not be planted until the soil is warm enough for prompt germination. The fields should be thoroughly tilled, especially in heavy soils, and the seed planted in a mellow seedbed. Planting in cold soil in the bottom of freshly opened lister furrows made by splitting previously unworked lister ridges often results in excessive seed rotting and poor stands. Seed rotting is most common in feterita, hegari, Club, Wonder, and similar soft-seeded types.

[6] *F. culmorum* (W. G. Sm.) Sacc.
[7] *P. oxalicum* Currie and Thom.

DISEASES OF LEAF AND SHEATH

Sorghum leaf diseases may range in severity from small, unimportant spots or stripes on the leaves to diseased areas covering practically the entire leaf. The relative severity may vary with the climatic conditions, the disease organism involved, and the susceptibility of the variety. Leaf diseases are generally favored by high temperatures and humid weather. Formerly the entire group of leaf diseases was frequently referred to under the general term "blight," but this name is now applied to one disease only.

The diseased spots or stripes are usually discolored because of chemical substances or pigments [8] that are produced in the plant cells whenever they are injured, whether by disease, insect puncture, or mechanical abrasions. In most varieties of sorghum and Sudan grass this pigment ranges from reddish or brownish purple to almost black. In broomcorn, most kaoliangs, and a few other sorghum varieties the spots or stripes on the leaves are red, while in shallu, Leoti sorgo, and Tift and Sweet Sudan grass they are tan. The particular pigment found in the leaf spots largely determines the color of the glumes (the scales that enclose the seeds) and also that of the spots found on the seeds. Although the color of the diseased areas depends to some extent on the variety of sorghum, their shape and other characteristics are different for the different diseases and are useful in identifying them.

Leaf diseases may be caused by bacteria or by fungi. Those caused by bacteria usually are characterized by the presence of drops or films of exudate that dry to thin, crustlike scales. Leaf spots caused by fungi have no exudate and usually are more or less roughened, owing to the presence of fungal fruiting bodies.

BACTERIAL LEAF DISEASES

Bacterial leaf diseases are likely to be found in the United States wherever sorghum is grown. Like most leaf diseases they are favored by warm (75° to 85° F.) moist weather. The organisms that cause these diseases are believed to be carried over from one season to another on the seed, on infected plant material in or on the soil, and occasionally on plants that overwinter. They may be spread from one leaf or plant to another by wind and splashing rain and also by insects. Infection takes place through the breathing pores of the leaves.

The bacterial diseases usually do not cause serious losses, because they generally do not develop fully until the plants have reached their full size. During warm, moist seasons, however, they may spread rapidly from the lower to the upper leaves until half to two-thirds of the leaf surface is destroyed. This materially reduces the forage value of the crop and may also interfere with the proper filling of the kernels.

Three bacterial diseases of sorghum are known in the United States: Bacterial stripe, bacterial streak, and bacterial spot.

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[8] The pigment is a natural plant dye called durasantalin and is not an anthocyanin pigment.

Bacterial Stripe

Bacterial stripe [9] is the most important and abundant of the three bacterial diseases. It attacks grain, forage, and sweet sorghums, broomcorn, and Sudan grass.

On sorghum the disease is characterized by long, rather narrow, somewhat irregular stripes, which usually are red and first seen on the lower leaves. The stripes are 1/4 inch to 9 inches or more long and tend to be confined between the leaf veins but may join together so as to cover a large part of the leaf surface (fig. 4, *A*). The ends of the stripes are either blunt or extended into long jagged points. The color is continuous throughout the stripe. Abundant bacterial slime or exudate occurs on the stripes. Unless washed off by rains, this dries and forms red crusts or thin scales, especially on the lower side of the leaves. The shape of the stripes is about the same on all varieties of sorghum, but their color varies somewhat on different varieties. For example, on Red Amber sorgo they are light brick red, on Early Amber sorgo and common Sudan grass they are dark purplish red, on kafir they are brownish red, while on certain other sorghums they are light to dark brown, with a yellowish-brown exudate.

Bacterial Streak

Bacterial streak [10] occurs on the leaves of sorghum and Johnson grass as narrow, water-soaked translucent streaks about 1/8 inch wide and 1 to 6 inches long. These streaks may occur on plants from the seedling stage to near maturity. At first no color is evident, except the light-yellow beadlike drops of exudate standing out on the young streaks. Later, narrow red-brown margins or blotches of color appear in the streaks, and after a few days the streaks are red throughout and no longer appear water-soaked or translucent. Parts of the streaks may broaden into elongated oval spots with tan centers and narrow red margins (fig. 4, *B*). When very numerous, the streaks may join to form long, irregular areas covering a considerable part of the leaf blade, and there may be more or less dead tissue with dark narrow margins between the reddish-brown streaks. At this advanced stage the bacterial exudate, which appeared as light-yellow drops on the young lesions, has dried to thin white or cream-colored scales.

Bacterial Spot

Bacterial spot [11] attacks the leaves of sorghum, broomcorn, Sudan grass, Johnson grass, pearl millet, foxtail millet, and corn. On sorghum the spots appear first on the lower leaves, and infection gradually spreads to the upper leaves as the plants approach maturity. The spots may occur on any part of the leaf and usually are circular to irregularly elliptical and from one twenty-fifth to one-third inch in diameter. At first they appear dark green and

[9] Caused by *Pseudomonas andropogoni* (E. F. Sm.) Stapp (formerly called *Bacterium andropogoni* E. F. Sm.).

[10] Caused by *Xanthomonas holcicola* (C. Elliott) Starr and Burk. (formerly called *Bacterium holcicola* C. Elliott).

[11] Caused by *Pseudomonas syringae* Van Hall (formerly called *Bacterium holci* Kendr.).

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water-soaked, but in a few hours the red color appears. These spots soon lose their water-soaked appearance and become dry and light-colored in the center, which usually is surrounded by a red border. The smaller lesions are often red throughout, with tiny somewhat sunken centers (fig. 4, *C*). The color bordering the lesions

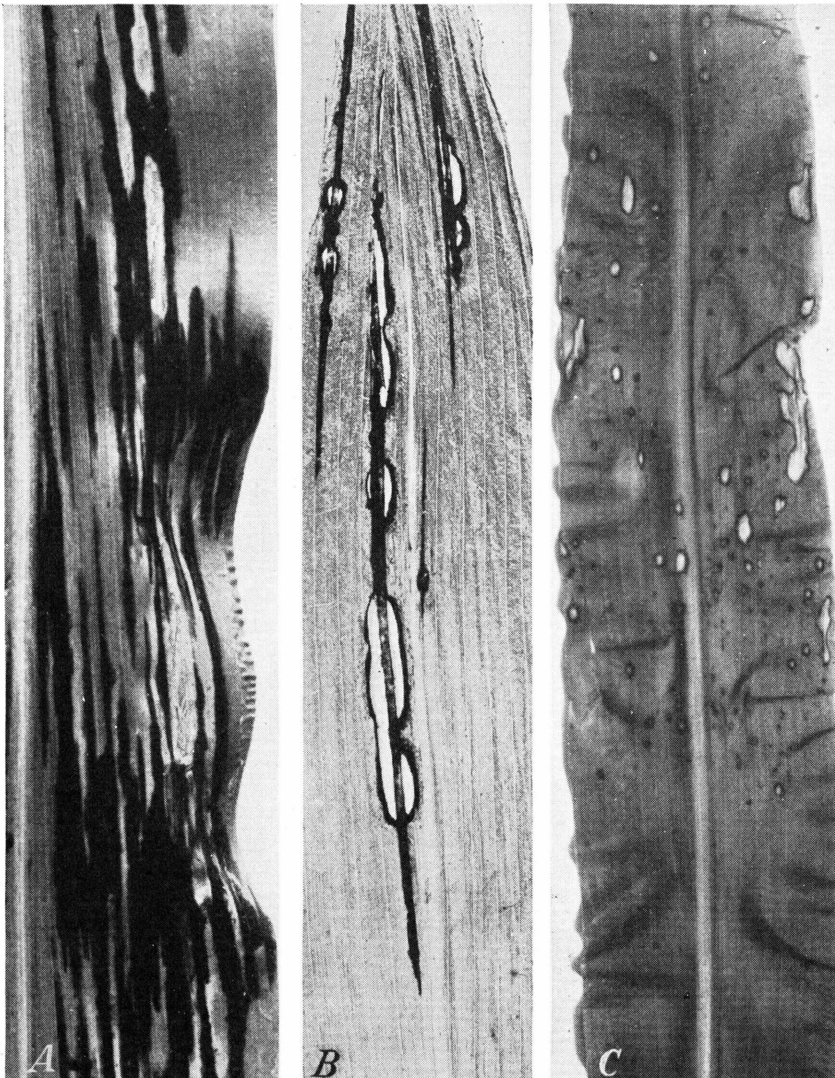

FIGURE 4.—Bacterial diseases on leaves of sorghum: *A*, Bacterial stripe; *B*, bacterial streak; *C*, bacterial spot.

varies somewhat in different varieties, being dark brown instead of red on shallu. Frequently the spots are so numerous that they unite into large diseased areas and cause the death of the whole leaf.

Control measures.—Recommended control measures for the three bacterial leaf diseases are sanitation, seed treatment, and the use of resistant varieties. Disposing of old infected plant litter and infected plants that overwinter, along with crop rotation, will reduce the quantity of inoculum present in the fields the next season. Seed treatment before planting will prevent the disease from being carried over on the seed. Leoti sorgo, Cody (Waxy Club), shallu, and Tift and Sweet Sudan grasses and certain crosses with these varieties are somewhat resistant to all three bacterial diseases. The sorgos as a class, however, seem to be more susceptible to bacterial stripe than are grain sorghums and Sudan grass. The kafirs are relatively resistant to bacterial streak.

FUNGUS LEAF DISEASES

Six distinct leaf diseases caused by as many different fungi are commonly found on sorghums in the United States, namely, rough spot, anthracnose, leaf blight, zonate leaf spot, gray leaf spot, and rust.

Rough Spot

The rough spot disease [12] is rather widespread in the Southeastern States. Although it doubtless had been present for many years, it was not observed in this country until 1937, when it was reported from Alabama and Georgia. Since then it has been found also in Florida, South Carolina, North Carolina, Louisiana, and Mississippi.

This disease attacks sorghum, Sudan grass, and Johnson grass. It is first observed as circular to oblong, light-colored spots. Then usually the red or tan pigment, depending on the variety, becomes apparent as the fungus spreads and injures the leaf tissue. Soon small black specks, the young fruiting bodies of the fungus, develop in the injured spots. On older leaves the spots are circular or elongated, grayish to yellowish-brown or purplish red, usually 1/8 to 1 inch long and 1/16 to 1/4 inch wide, running lengthwise of the leaf (fig. 5, *A*). As the spots enlarge, they grow together so that the size of diseased areas is extremely variable. In some cases they are surrounded by a reddish or tan border, depending upon the variety, while in others no color develops. Sometimes the pigment is distributed as small specks throughout the infected areas. The most striking characteristic of rough spot is the abundant development of small black fruiting bodies (pycnidia), usually on the surface of the diseased discolored area, but occasionally on green healthy-appearing parts of the leaf surface. When the affected areas are rubbed between the fingertips, the sandpaperlike roughness, caused by the hard, raised fruiting bodies, can be detected readily (fig. 5, *B*). By the time the leaves die and become dry and papery, the fruiting bodies often are so abundant that they cover most of the leaf surface. Similar lesions occur on the leaf sheaths and occasionally on the stalks.

The extent of injury from this disease has not been determined. Obviously the disease decreases the forage value of the crop materially

[12] Caused by *Ascochyta sorghina* Sacc.

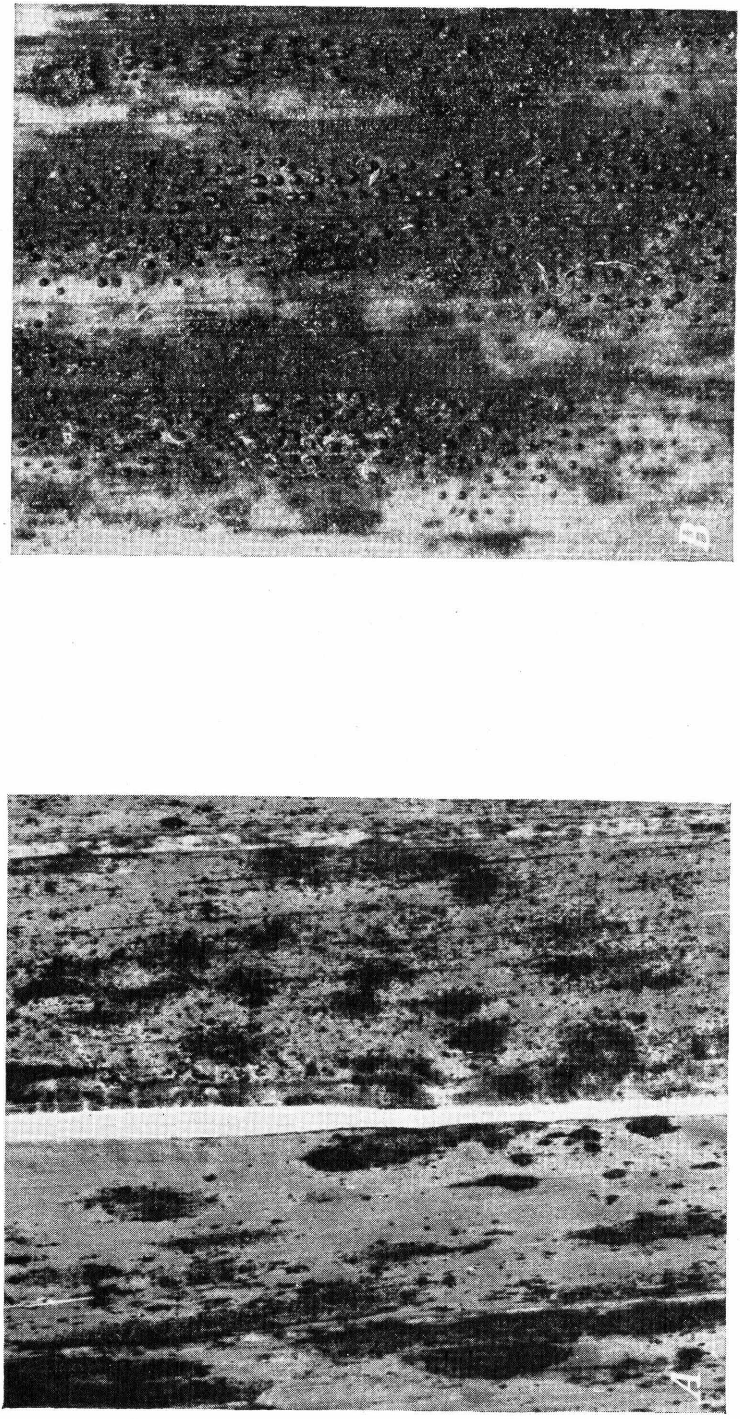

FIGURE 5.—Rough spot on leaves of Georgia Blue Ribbon sorgo, showing: *A*, Variation in size and shape of spots (slightly enlarged); and *B*, raised black fruiting bodies of the fungus (considerably enlarged), which give the leaf a rough "sandpaper" feeling.

and also the production of sugar in the stalk by discoloring and killing large parts of the leaves prematurely. Many of the dried leaves are lost in harvesting. The fungus often fruits abundantly on the glumes or chaff covering the seed and thus its use offers a means of spreading the disease. Observations indicate that the disease is heaviest where sorghum or Sudan grass is grown on the same land for several seasons and that it increases in intensity with the continuous growing of these crops. Relatively little injury from rough spot has been observed on sorghum or Sudan grass in experimental plots located on land that had been in other crops. The number of years that the fungus is carried over in the soil is not known.

There appears to be a difference in the relative susceptibility of varieties of sorghum to rough spot. The following varieties were relatively free from this disease in preliminary tests for resistance: Schrock (a grain sorghum) and the Straightneck, Silvertop, and McLean sorgos. One noncommercial grain sorghum, Smith milo-kafir, seems to be resistant, while another, similar to kafir and selected from the cross Dawn kafir × (Kansas Orange × milo), is resistant to rough spot as well as to anthracnose, rust, and smut.

Control measures.—Sorghum or Sudan grass should not be grown on land where rough spot occurred the preceding season. Seed treatment and the use of available resistant varieties are advisable.

Anthracnose

Anthracnose occurs commonly on the leaves of sorghums and Sudan grass grown in the South. It is caused by a fungus [13] that is carried on the seed and lives in the soil and in dead and decaying plant refuse. Infection takes place and often causes spots to develop on the leaves when plants are still in the seedling stage and later spreads to other leaves as they appear. At first the spots are small, circular to elliptical, about one-sixteenth inch in diameter, and are reddish purple on most varieties (fig. 6). Later, the spots enlarge and may unite to form large areas of dead tissue. As the disease develops, the centers of the spots fade to a grayish-straw color surrounded by a reddish-purple border. Under favorable conditions the spots enlarge until they merge and thus kill a large part of the leaf. The leaf midribs are often strikingly discolored. In many of the spots, a blackish growth appears. When the leaf is held up to the light or is examined under a magnifying glass, this black growth is seen to be made up of very short stiff hairs that are a part of the fruiting bodies of the fungus.

Control measures.—The only practical control measure appears to be the growing of resistant varieties. Among the sorghums recently tested the following varieties of sorgo (sweet sorghum) that appear to be somewhat resistant are Atlas, McLean, Folger, Denton, Planter, Straightneck, Silvertop, Cowper, Hodo, C. P. Special, Leoti, and Georgia Blue Ribbon. Grain sorghums that appear to be resistant include shallu, Spur feterita, and two noncommercial varieties, Smith milo-kafir and Dawn × (Kansas Orange × milo). Some varieties, however, including Schrock, shallu, and Leoti, seem to be resistant in

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[13] *Colletotrichum graminicolum* (Ces.) G. W. Wils.

FIGURE 6.—Anthracnose on leaves of Saccaline sorgo: *A*, Young isolated spots; *B*, older spots that have grown together. (Both slightly enlarged.)

one locality and susceptible in another. All lots of Sudan grass obtained from various regions in the United States were found to be completely susceptible to this disease. Attempts are being made to breed strains resistant to anthracnose and some of the other leaf spots. One such strain, Tift Sudan, distributed to farmers in Georgia in 1942, showed considerable resistance but is not immune.

Leaf Blight

Leaf blight[14] is most prevalent in the warmer humid Atlantic and Gulf Coastal Plains of the Southern and Southeastern States, where it causes serious losses in sorghums and Sudan grass. It also attacks corn. It is probably the most destructive Sudan grass disease of this area. In some years it has caused considerable injury also to Sudan grass in New York, Pennsylvania, Ohio, Wisconsin, and Minnesota. The causal fungus is carried on the seed and lives in the soil on dead or decaying plant material. It may cause seed rot and seedling blight of sorghums and Sudan grass, especially in cold and excessively moist soil. Under such conditions seedlings can become infected readily and many either die or develop into plants that are greatly stunted. Small reddish-purple or yellowish-tan spots usually develop on the leaves of infected seedlings (fig. 7). Under conditions favorable for their development, these spots enlarge so as to come together and cause the leaves to wrinkle, wilt, and turn purplish gray. On infected leaves of older plants that are not killed, the spots gradually enlarge and form long elliptical areas, one-eighth to one-half inch wide and several inches long. These spots may emerge sufficiently to kill large parts of the leaves, which then wither to such an extent that badly affected plants appear as if they had been frosted. The center of the individual spots usually is grayish to straw-colored and is surrounded by reddish-purple (fig. 8) or tan borders, depending upon the variety.

A greenish moldlike growth of spores develops in the center of the leaf spots during warm humid weather. These spores are scattered by wind or rain and infect other leaves. When weather conditions are favorable the disease spreads rapidly and may cause serious damage by killing parts or all of the leaves before the plant has matured.

Control measures.—The chief hope of controlling leaf blight lies in the development of resistant varieties. The following varieties of sorghum appear to be somewhat resistant: Most kafirs and certain kafir crosses—Quadroon, Early hegari, Spur feterita, shallu, Smith milo-kafir, Dawn × (Kansas Orange × milo)—and Atlas, McLean, Gooseneck, Norkan, Denton, and Cowper sorgos. All commercial strains or lots of Sudan grass that have been tested are highly susceptible. Plant breeders are attempting to develop a resistant strain of Sudan grass from crosses between Sudan grass and resistant varieties of sorghum. Tift Sudan, distributed to farmers in Georgia in 1942, shows some resistance, but is not immune. Rotation does not appear to be an effective method of control, because the fungus lives in the soil for several years. Seed treatment may prevent some seedling infection and spread of the disease to new areas.

[14] Caused by *Helminthosporium turcicum* Pass.

Zonate Leaf Spot

Zonate leaf spot[15] is a recently discovered disease that attacks sorghum, Sudan grass, Johnson grass, and also sugarcane, corn, and cattail or pearl millet. It has been observed in Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida, Mississippi, and

FIGURE 7.—Sudan grass seedlings infected with and almost killed by leaf blight.

Louisiana. The disease is very conspicuous on sorghum leaves as reddish-purple bands of tissue alternating with tan- or straw-colored areas, forming a zonate pattern. The spots often occur along the margins of the leaves, forming semicircular patterns (fig. 9, *A*), or they may

[15] Caused by *Gleocercospora sorghi* D. Bain and Edg.

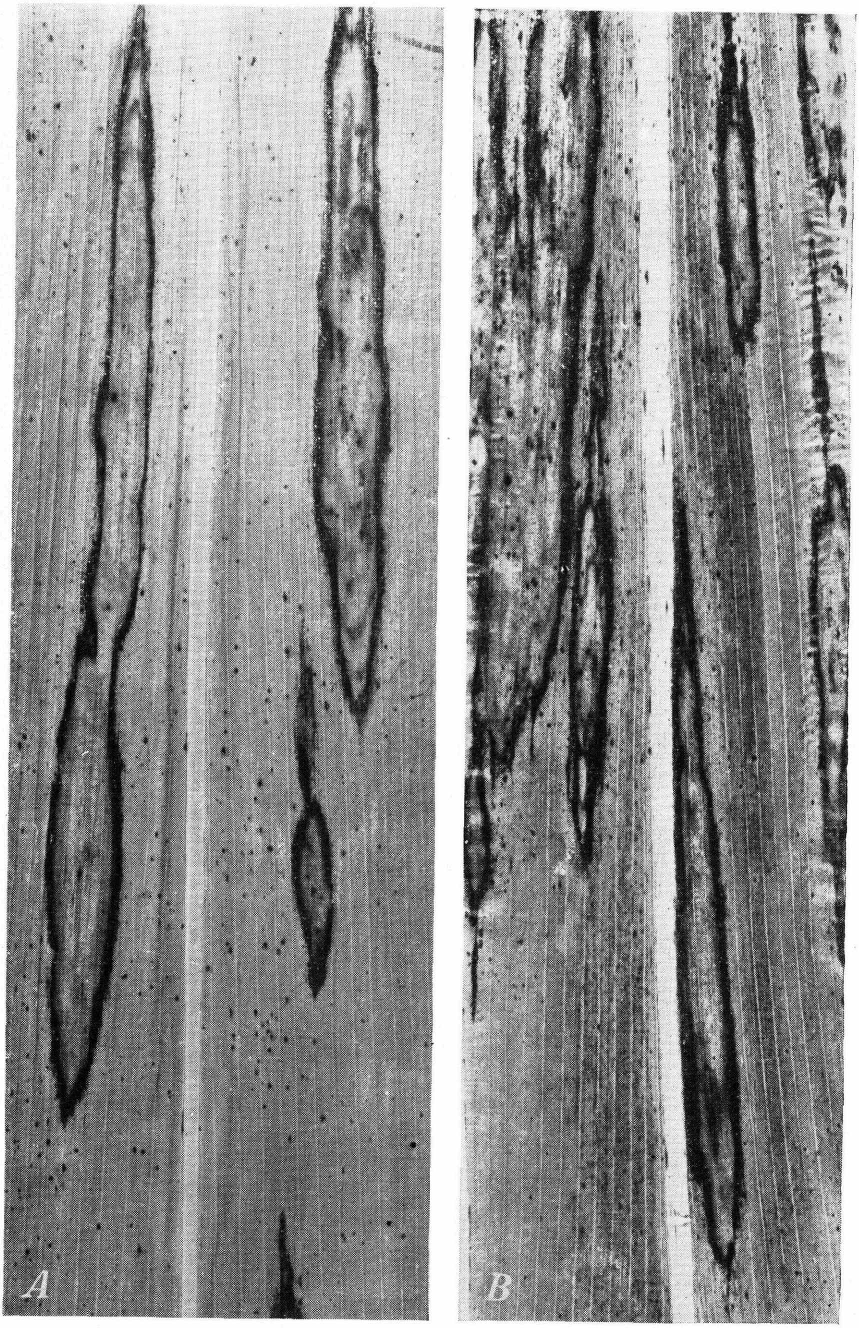

FIGURE 8.—Leaf blight on Planter sorgo, showing: *A*, Medium infection, in which diseased areas are joined to form long streaks; and *B*, very severe infection, involving a large part of the leaf.

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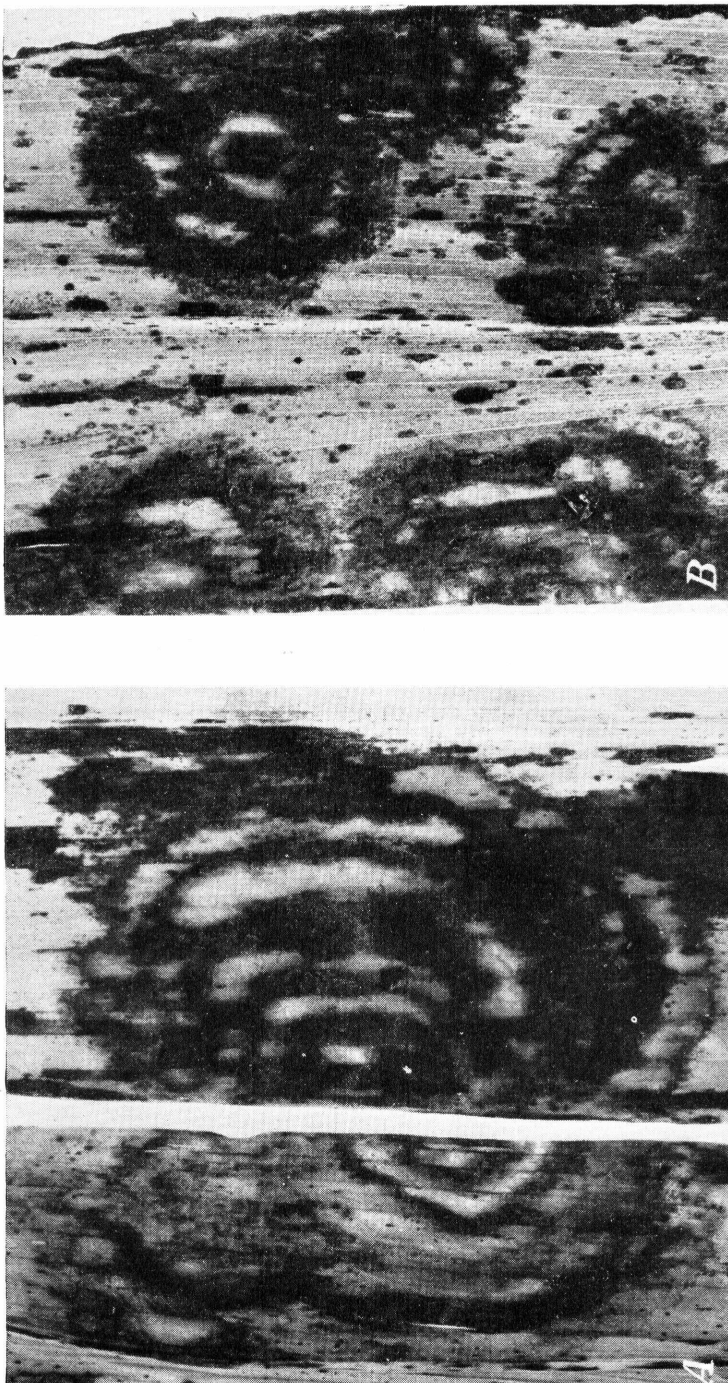

FIGURE 9.—Zonate leaf spot: *A*, On Atlas sorgo; *B*, on Jones sorgo. (Both slightly enlarged.)

occur on other parts of the leaf, where they are more nearly circular and show more strikingly their irregular borders (fig. 9, *B*). These irregular spots or blotches vary greatly in size. At first the spots may be only a fraction of an inch in diameter, but as they become older they may reach several inches in length, and when numerous they often unite to cover most of the leaf surface.

Not much is known about the damage caused by this disease, but when plants are so heavily infected that the leaves are killed prematurely, the forage value of the crop is undoubtedly reduced.

Control measures.—No fully proved measures are known. The fungus has been found on the glumes and seed, which suggests that the planting of disease-free or adequately treated seed would help to prevent the spread of the disease. No highly resistant varieties are known.

Gray Leaf Spot

Gray leaf spot[16] occurs on sorghum, Sudan grass, Johnson grass, and corn. It is not certain, however, that the races that attack corn are the same as those that attack sorghum. On the whole, the disease is of minor importance, but occasionally it causes considerable spotting of sorghum leaves in limited areas in the more humid and warmer sections, particularly in the Gulf States. It is commonly found on Johnson grass growing along highways and fences.

The spots usually are reddish purple, but in some varieties they are tan. When small they are indistinguishable from other leaf spots, but as they enlarge they become long and narrow, being limited somewhat by the leaf veins (fig. 10, *A*). These long, narrow spots may come together and thus destroy large areas of the leaves (fig. 10, *B*). As the spots enlarge, they usually become covered with a grayish-white fuzz, made up of the fruiting structures of the fungus.

Control measures.—As in the case of other leaf diseases of sorghum, the development of resistant varieties appears to be the most feasible control measure. The reaction of sorghum varieties to this disease, however, is not yet known.

Rust

Sorghum rust[17] attacks Sudan grass and Johnson grass, as well as most varieties of sorghum. It occurs frequently in the humid Gulf Coast region and occasionally during wet seasons in States as far north as Kansas and Indiana. Usually it does not become evident until the seed is well developed, so that it causes relatively slight losses to the grain-sorghum crop. Abundant rust, however, causes the leaves to dry and break off so that the forage value of the crop may be lowered.

Rust appears on the leaves as raised pustules or blisters covered with a brownish coating that eventually breaks open and allows the dark chestnut-brown rust spores to escape. These pustules occur on both the upper and lower surfaces of the leaf. Before the pustules appear, small purple, red, or tan spots may be seen at the points where the infection is developing. As the pustules develop, the colored regions around them become larger and considerable areas of the leaves may be destroyed (fig. 11, *A*). The method by which sorghum rust

[16] Caused by *Cercospora sorghi* Ell. and Ev.
[17] Caused by *Puccinia purpurea* Cke.

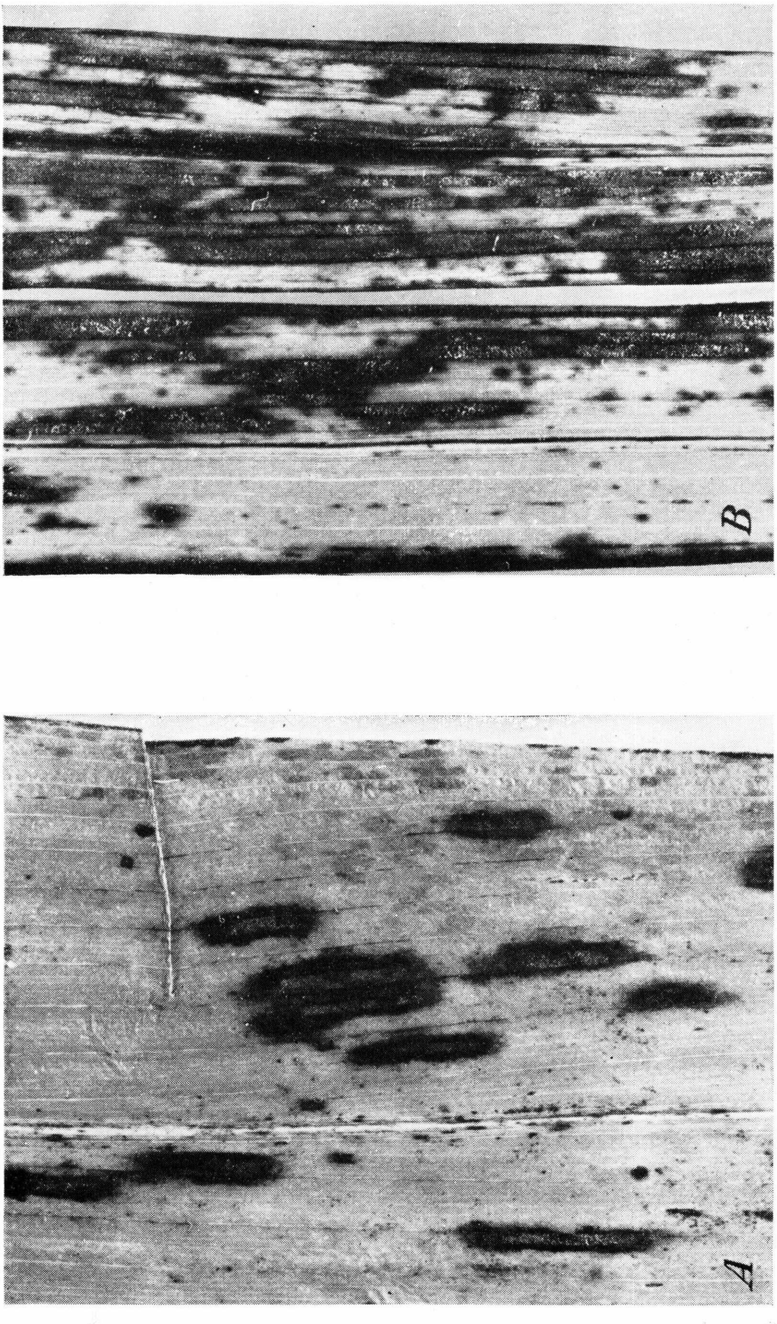

FIGURE 10.—Gray leaf spot: *A*, On leaf of Hodo sorgo (enlarged slightly); *B*, on leaf of Johnson grass (considerably enlarged).

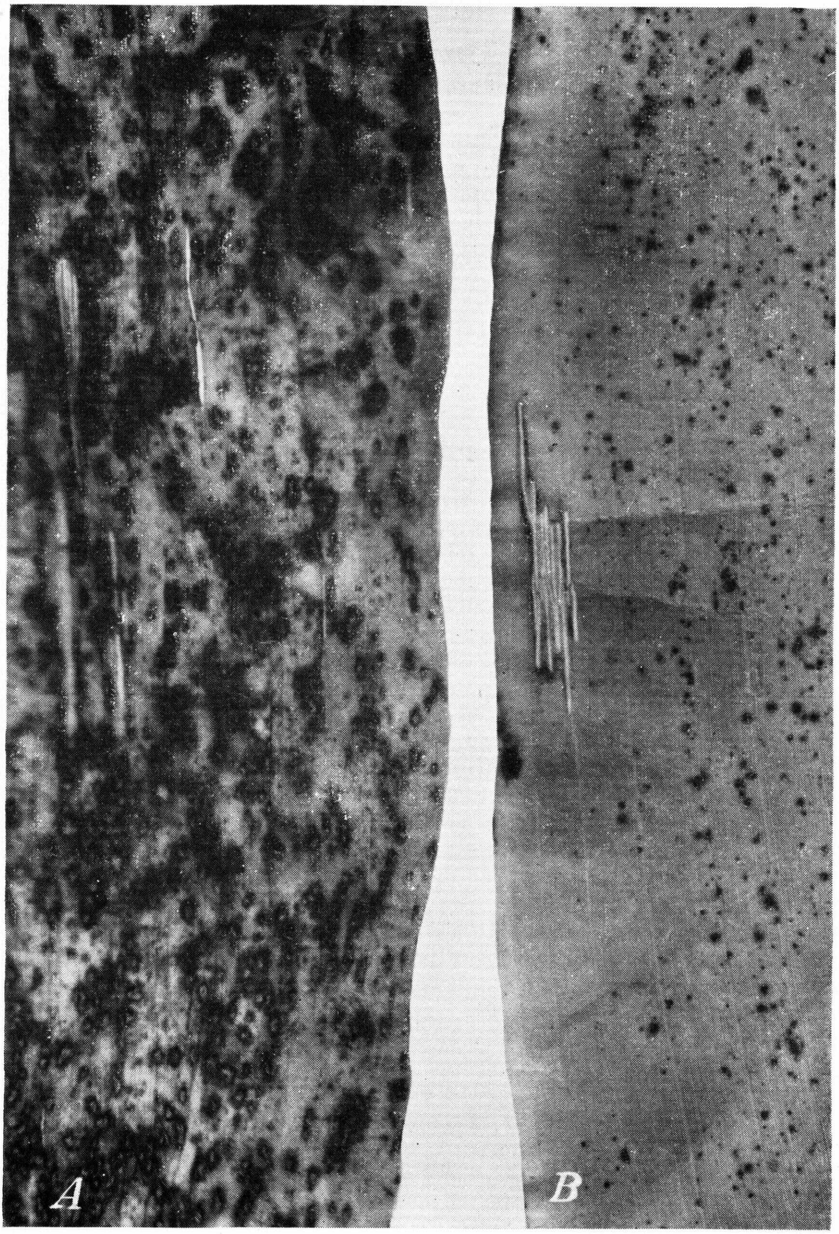

FIGURE 11.—Rust: *A*, On a susceptible variety of sorghum; *B*, on a resistant variety.

is carried over winter is not known, but the abundance of Johnson grass throughout the South suggests that this plant might serve as the principal overwintering host for the fungus. In that section Johnson grass, as well as some of the sorghums, is in condition for the development of rust on the leaves by July. If wet weather prevails as the season advances, the rust may spread northward, where the sorghums mature later.

Control measures.—Growing resistant varieties is the only feasible method for controlling sorghum rust. Milos, certain hybrid strains involving milo, and shallu appear to be the only sorghums that are highly resistant (fig. 11, *B*). Kafirs and sorgos tend to be moderately susceptible, and feteritas highly susceptible. Broomcorn and Sudan grass also are susceptible.

Nonparasitic Leaf Discolorations

Certain environmental conditions or hereditary factors occasionally produce symptoms on leaves of sorghum and Sudan grass and these are frequently confused with symptoms produced by fungus or bacterial diseases. A very common condition in sorghum is the presence of intensely colored leaf spots or stripes without any other indication of disease symptoms. Some of these patterns are shown in figure 12. Certain varieties of sorghum are more subject to such spotting than others. The spots or stripes are not covered with bacterial exudate or scales; they do not consistently have dead areas in or around them; and they show no evidence of the presence of fungus mycelium or fruiting bodies. Much of this nonparasitic spotting may be due to mechanical injuries from insect punctures, wind, or sand particles. When grasshopper bait containing arsenic or chlorate weed-killing chemicals falls on the leaves of sorghum, it causes a burning effect in irregular but characteristic spots that resemble those caused by parasitic leaf diseases. Often, however, the cause of this leaf spotting apparently is a physiological break-down of the leaf tissues. Occasional plants have leaves so badly discolored that most of their leaf area is involved (fig. 12, *A*). The spots may be solid, or they may follow various concentric or irregular patterns. Certain of these latter types are known to be hereditary.

One of the most common types of nonparasitic leaf discolorations is the chlorotic (yellow or yellow-striped) appearance of the leaves of second-growth sorghum and Sudan grass. Nutritional deficiencies are believed to be the cause of this condition, but their exact nature has not been determined. Varieties differ with regard to the extent of this chlorotic development in the new growth that follows the harvesting of the crop. A similar chlorotic condition in first-growth sorghum has been observed in certain varieties, particularly milos, growing on highly calcareous soils, especially where there are outcrops of caliche, which consists largely of calcium carbonate. Other chlorotic disturbances are definitely hereditary in nature. Plant breeders have isolated numerous strains that produce white or yellow seedlings or plants with striped leaves and stems (fig. 12, *C*). One such leaf with what is called "zebra stripe" is shown in figure 12, *F*.

Control measures.—The remedy for hereditary defects and for those nutritional deficiencies that affect varieties differently is to choose varieties or seed stocks that produce only normal healthy plants.

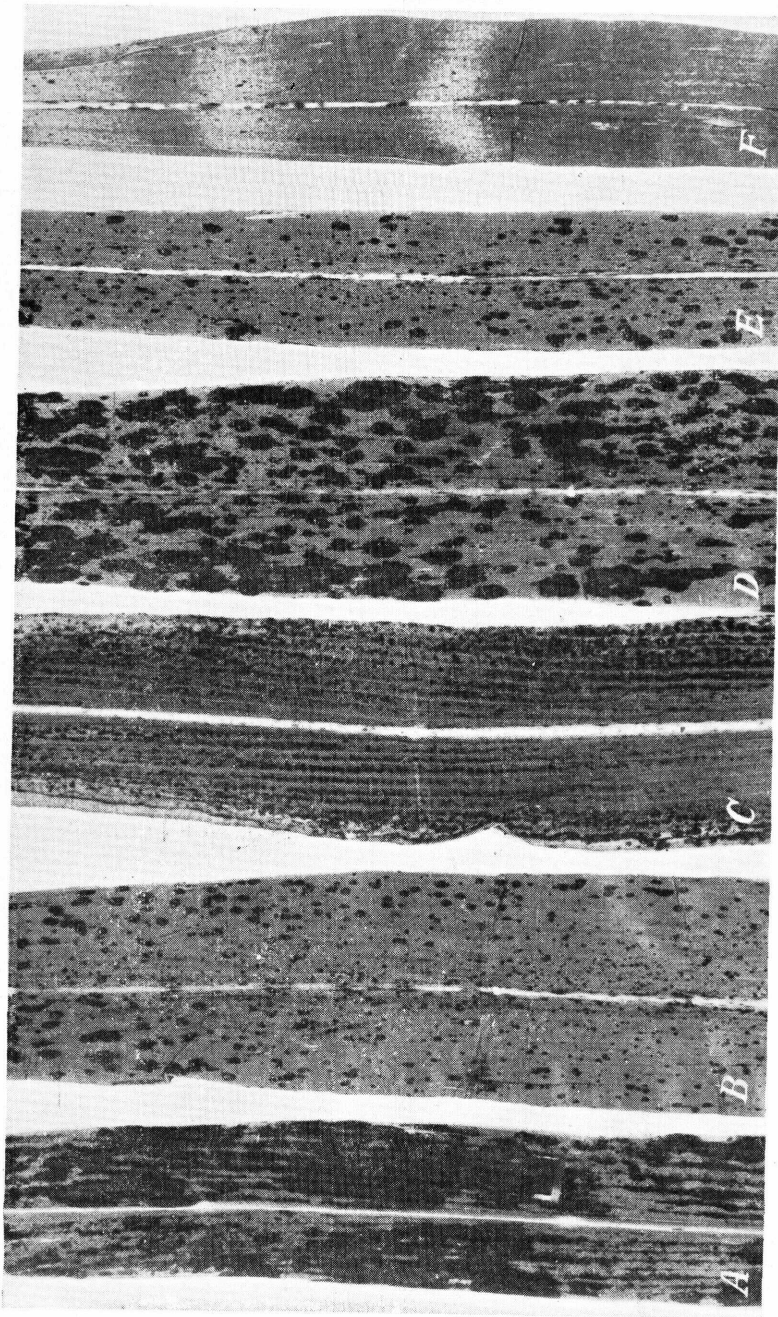

FIGURE 12.—Nonparasitic leaf patterns: *A*, On Sudan grass (resembles bacterial stripe); *B*, on Atlas × Tift; *C*, on Tift × McLean sorgo (green almost all masked on many leaves); *D*, on Colman sorgo (resembles *B*, but spots are larger and often merge); *E*, on Sudan grass; *F*, on Sudan grass (so-called "zebra-stripe," alternate light- and dark-green zones).

DISEASES ATTACKING THE HEAD

The smuts are practically the only diseases in which injury to the plant is confined almost entirely to the head, although certain root and stalk rots sometimes check normal head development. In the United States, there are three smuts of sorghum: Covered kernel smut, loose kernel smut, and head smut.

Covered Kernel Smut

Covered kernel smut is caused by a fungus [18] that attacks all groups of sorghum, including Johnson grass. It probably is the most destructive disease of sorghum in the United States. Although it occurs wherever sorghum is grown, it is most prevalent in the Kansas-Oklahoma-Texas area. Usually all, but occasionally only a part, of the kernels on a smutted plant are destroyed. In smutted heads, enlarged cylindrical or cone-shaped smut galls are formed instead of the kernels (fig. 13). At first these smut galls are covered with a light-gray or brown membrane that later may break and release the dark-brown spores. Some of the spores thus released are scattered in the field to nearby healthy heads, but most of them remain in the galls until the crop is threshed. Threshing breaks up the galls and spreads the spores to the healthy seeds.

When this smutted seed is planted, the spores germinate along with the seed. The growing fungus then invades the developing seedling and continues to grow undetected inside the plant until after heading, when the smut galls, which have formed in place of the kernels, become evident. Plants affected by covered kernel smut appear normal except for the smutted heads.

At least five strains, or races, of covered kernel smut are known. These races differ with regard to their ability to attack different varieties of sorghum. As far as is known, all commercial varieties of sorgo, kafir, durra, broomcorn, and also Sudan grass are susceptible to all five races, as also are some miscellaneous varieties, including darso, Schrock (Sagrain), Dwarf Freed, and various others.

Hegari and the true varieties of milo are resistant to race 1, the most common race of covered kernel smut, and to certain others, but are readily attacked by race 2. This race frequently does not affect the entire head in milo and hegari, but, nevertheless, it often causes severe losses.

Common, or standard, feterita is generally resistant to all races of covered kernel smut except race 3, to which it is moderately susceptible. Races 4 and 5 attack certain varieties or crosses that are not susceptible to race 1 and differ in their susceptibility to races 2 and 3. Spur feterita and certain hybrids derived from it, so far as known, are highly resistant to or immune from all races of covered kernel smut.

Control measures.—Covered kernel smut can be effectively controlled by properly treating the seed, planting only smut-free seed, or growing resistant varieties. Because it is not safe to assume that seed is entirely free from smut and because resistant varieties of all types of sorghum are not available, seed treatment is the most logical means of control.

[18] *Sphacelotheca sorghi* (Lk.) Clint.

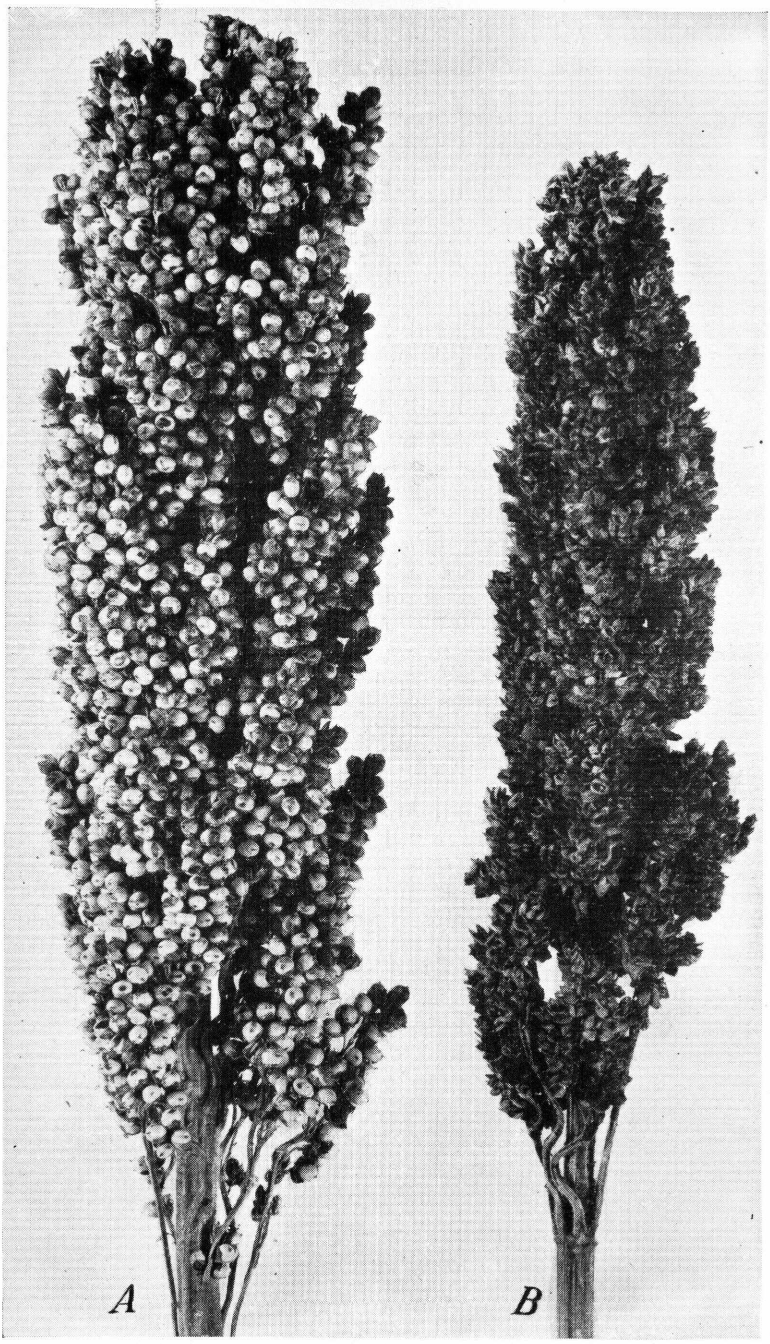

FIGURE 13.—Covered kernel smut on sorghum: *A*, Sound head; *B*, infected head, in which the kernels are replaced by masses of smut spores.

Materials for seed treatments and methods of applying them are discussed on page 42.

Loose Kernel Smut

Loose kernel smut [19] is much less common than covered kernel smut, but it occurs occasionally, particularly in the southern Great Plains. It attacks all the groups of sorghum, including Sudan grass and Johnson grass, although certain varieties in some groups are immune or highly resistant.

The galls formed by loose kernel smut are long and pointed and the thin membrane covering them usually breaks soon after the galls reach full size. Most of the dark-brown spores are soon blown away, leaving a long, dark, pointed, curved structure, called a columella, in the central part of what was the gall (fig. 14). As in covered kernel smut, the spores of the fungus are carried on the seed and germinate soon after the seed is planted, when the fungus grows into the young sorghum plant. Here the fungus continues to grow unobserved inside the plant until after heading, when the long pointed smut galls appear in the heads in place of normal kernels. Unlike covered kernel smut, however, this disease stunts the infected plants and frequently induces the development of abundant side branches.

Loose kernel smut, in addition to being seed-borne and able to infect sorghum seedlings, may cause secondary infection; that is, the spores from a smutted head may infect and cause smut to develop in late heads on otherwise healthy plants.

Loose kernel smut comprises at least three races that differ in their ability to attack different groups of sorghum. Certain of the feteritas and milos, Schrock, and Dwarf Shantung kaoliang are resistant to at least two races; Premo, Red Amber, shallu, and Weskan are highly susceptible to two; and a large number of other varieties are susceptible to one race and resistant to the others. Johnson grass, as found in the Southwestern States, usually is heavily infected with a loose kernel smut that is the third race to be discovered. This smut is able to attack several varieties of sorghum, including Sudan grass.

Control measures.—The control measures for loose kernel smut are the same as those for covered kernel smut; namely, seed treatment and the use of smut-free seed and of resistant varieties. The treatments that control covered kernel smut will also control loose kernel smut, and varieties that are resistant to the five races of covered kernel smut usually are resistant also to the races of loose kernel smut.

Head Smut

Head smut [20] attacks sorghum, Sudan grass, and, to some extent, corn. It is not common in the United States, but occasionally is somewhat damaging in individual fields of some varieties of sorghum in Kansas. Although head smut has been known in this country since 1890 and has been observed in many States since that time, the total losses from it have been small.

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[19] Caused by the fungus *Sphacelotheca cruenta* (Kuehn) Potter.

[20] Caused by the fungus *Sphacelotheca reiliana* (Kuehn) Clint. (formerly called *Sorosporium reilianum* (Kuehn) McAl.).

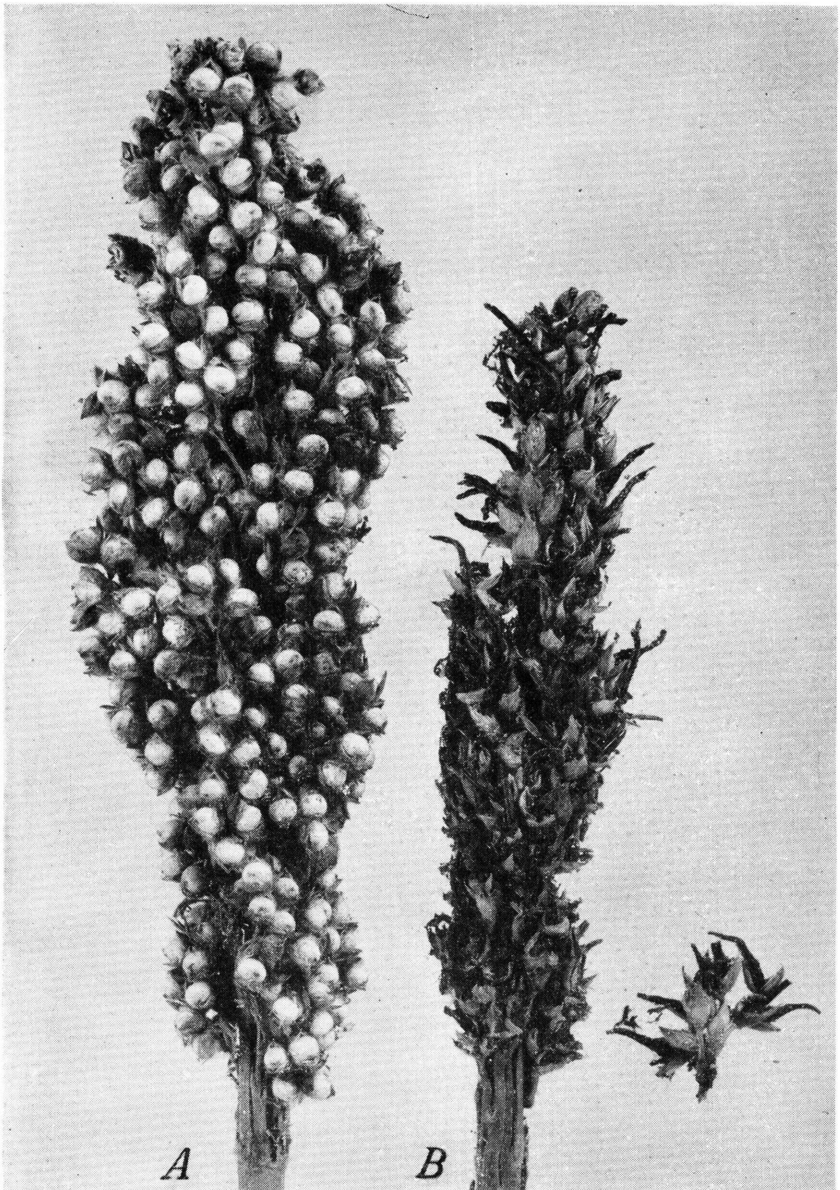

FIGURE 14.—Loose kernel smut on sorghum: *A*, Healthy head; *B*, head infected with loose kernel smut; kernels have been replaced by smut masses, which have been largely blown away, leaving the prominent columellas.

Head smut is distinguishable from the kernel smuts because it destroys the entire head, transforming it into a large mass of dark-brown powdery spores (fig. 15). The smut first becomes evident at heading time, when the large gall bulges out of the boot. At first the gall is covered with a whitish membrane, which soon breaks and allows the spores to be scattered by the wind and rain to the soil and

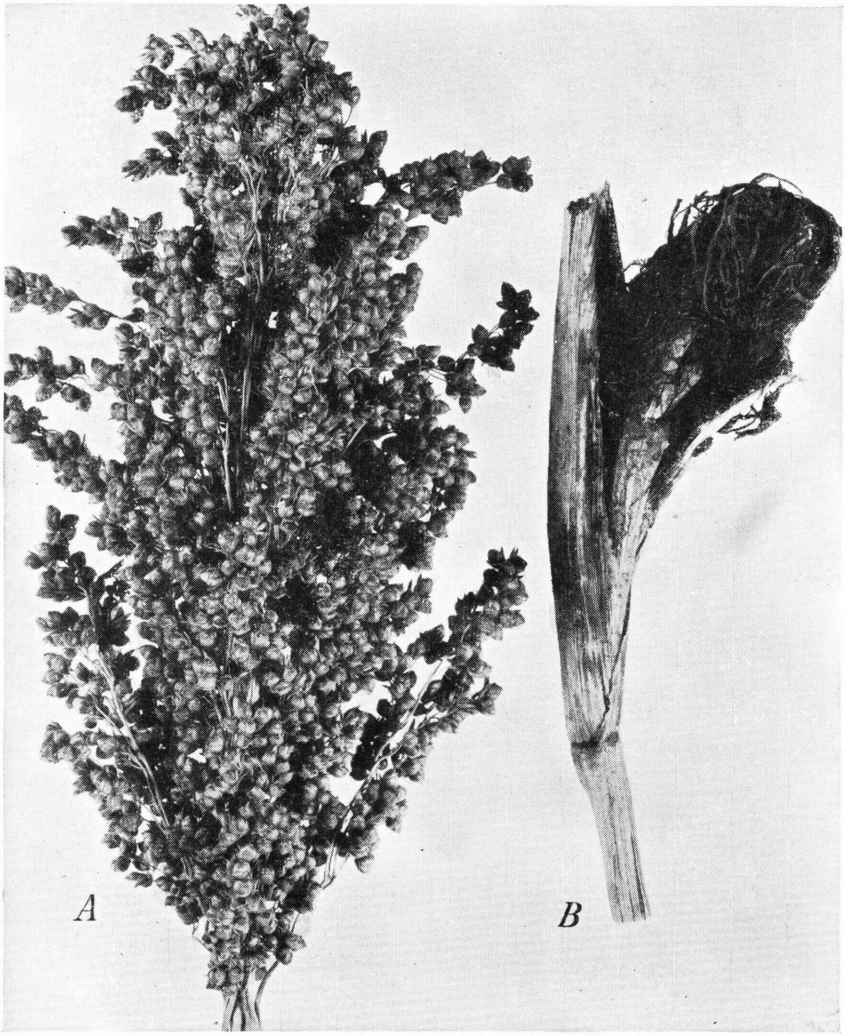

FIGURE 15.—Head smut on Leoti sorgo: *A*, Healthy head; *B*, smutted head.

to plant refuse, where they overwinter. The following spring and summer the spores germinate and produce smaller spores of another type, which in turn infect the sorghum plants. After invading a sorghum plant, the fungus grows within it until the plant reaches the heading stage, when the smut gall becomes evident.

Since this smut fungus is carried in the soil, sorghum grown from clean seed planted on infested soil may be attacked. Some of the smut spores from the broken galls also may contaminate the seeds produced on nearby healthy plants. When such infested seeds are sown, head smut may be introduced into the soil of previously noninfested fields. It is the spores that are in the soil, however, from whatever source, that bring about infection of the plant and cause the heads to be smutted.

Head smut also destroys the tassels and ears of corn in a manner similar to the destruction of the heads of sorghum. It is not certain, however, that the head smut disease can be transmitted from corn to sorghum or from sorghum to corn. It seems likely that corn and sorghum are attacked by different races of this fungus, each race being restricted to one particular crop plant.

Control measures.—Sanitation is the chief means of controlling head smut. If seed that came from a field containing plants infected with head smut must be used for planting in an uninfested area, it should first be treated with a good dust fungicide (see p. 44) to prevent spreading the smut to the soil in this area. If head smut is discovered in a field, the infected plants, or at least the galls, should be removed and burned before the spores are scattered. This is usually feasible in most fields in which the disease is found, as only a few of the plants are smutted. Prompt destruction of all smut galls usually rids a farm of head smut in a few years. Head smut seems to be severely damaging only to sorgos, durras, and varieties developed from hybrids with these two sorghum groups. Kafirs and Sudan grass show only moderate susceptibility, while milo, feterita, and broomcorn are seldom, if ever, attacked. Among the sorgos, Red Amber, certain strains of Black Amber, and varieties apparently derived from Amber crosses, including Leoti and Colman, seem to be particularly susceptible.

ROOT AND STALK DISEASES

The most important root and stalk diseases of sorghum are pythium root rot (milo disease), weak neck, and stalk rot. Except for pythium root rot, which under some conditions may appear at a relatively early stage, these diseases usually do not become evident until the plants are almost mature.

Pythium Root Rot

Pythium root rot (milo disease) is caused by a fungus [21] that under certain conditions attacks also sugarcane, wheat, corn, and many other grasses. It has been especially destructive to milo. It was first discovered in 1925 near Chillicothe, Tex., and near Garden City, Kans., where it occurred on irrigated land that had been cropped to milo for several years. Since then the disease has been observed in numerous fields in the western parts of these States and in Oklahoma, New Mexico, Nebraska, Arizona, and California. In California it has been extremely destructive on subirrigated lands.

As far as is known, the disease does not damage sorghum on new land, or for that matter on any land not cropped previously to milo or milo derivatives, including darso. It is the most serious disease

[21] *Pythium arrhenomanes* Drechs.

known on milo, darso, and their hybrids and, until resistant varieties became available, was a limiting factor in the growth of these varieties in infested areas. Other sorghums, with few exceptions, are not affected.

In heavily infested soil, the disease may appear 3 to 4 weeks after planting, when the plants are only 6 to 9 inches high. The first indication of the disease is a stunting of the plants and a slight rolling of the leaves, with the older leaves turning light yellow at the tips and margins. This yellowing and drying progresses until all the leaves are affected and the plants die, usually without heading. They appear as though injured by excessive drought, alkali, or chinch bugs (fig. 16). In less heavily infested soil, the disease may not appear until

FIGURE 16.—Pythium root rot on Colby milo: *A*, Plants grown in pythium-infested soil (foreground); *B*, plants grown in similar soil that was disinfected with chloropicrin several weeks before planting (background).

the plants are about ready to head. In such cases it progresses less rapidly; the plants may grow weakly until late in the season and may form small poorly filled heads.

The disease attacks the roots before the above-ground parts of the plants show any symptoms. When affected plants are only a few inches tall, examination reveals a water-soaked brown or reddish discoloration of the outer part of the roots. Later, a soft rot destroys most or all of the fine root system and the outer part of the larger roots, while the central part of the latter turns dark red or brown.

The tissue at the base of the crown also turns dark red, and this discoloration extends up into the base of the stalk (fig. 17). The disease is commonly recognized by splitting the base of the diseased plant and finding this dark-red area in, above, and below the crown.

After the disease first appears in a field, it usually becomes more severe each successive year as long as milo or other susceptible varieties are grown. It may appear at first in a few isolated spots in which the plants are stunted or retarded or may have died prematurely. The following year, these areas will be larger and the plants growing on them will be more severely affected. If a susceptible variety is grown a third year, the entire crop may be completely destroyed early in the season.

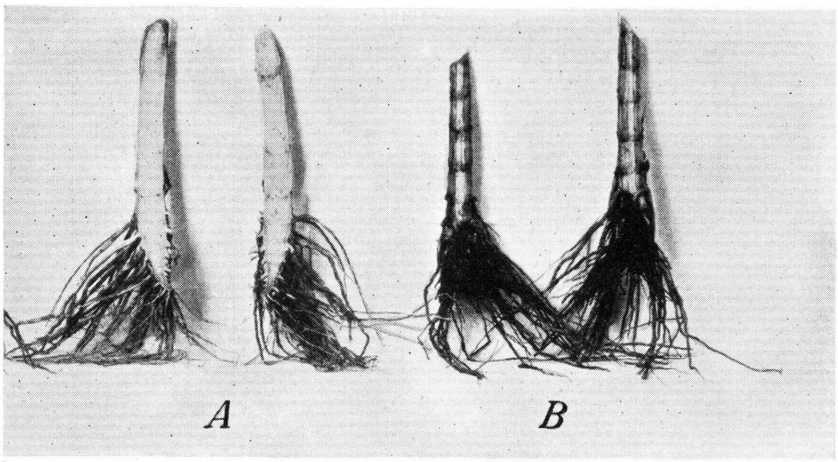

FIGURE 17.—Pythium root rot (milo disease) on Dwarf Yellow milo. Bases of healthy and diseased stalks split so as to show interiors: *A*, Healthy; *B*, infected with the fungus.

The disease may be spread by soil or carried in runoff or irrigation water and by farm implements, wind-blown soil, or by any agency that transports soil from infested fields. As far as is known, it is not transmitted by the seed and is not controlled by seed treatment. Although small areas of badly infested soil can be effectively sterilized by steam, formaldehyde, chloropicrin (fig. 16), or other agents, so that susceptible varieties can be safely grown, this is not economically feasible or practicable for field use.

Certain abnormal conditions of sorghum caused by environmental conditions or hereditary factors at times have been mistaken for symptoms of milo disease. For example, at times stunted or rosetted sorghum plants have been observed in low spots in irrigated fields where the soil had become partly waterlogged after being submerged for some time under irrigation water. Such plants, however, show poor root development, which suggests that the unthrifty condition may be due to insufficient aeration of the wet soil. The stunting of the plants and the rolling and discoloring of the leaves, however, are suggestive of milo disease.

A hereditary defect called "headless," which prevents the formation of heads and sometimes side branches on most of the stalks of the

plants inheriting that tendency, also has been mistaken for symptoms of milo disease. The "headless" defect has appeared spontaneously on several varieties that are resistant to milo disease.

Control measures.—Effective control measures are limited to the growing of resistant varieties. Fortunately, highly resistant strains of all desirable but hitherto susceptible varieties of milo have been developed. Finney milo, the first resistant selection, was developed from Dwarf Yellow milo at Garden City, Kans., and is now grown in Kansas, Texas, and New Mexico. Later Texas milo was selected from Dwarf Yellow milo by the Texas Agricultural Experiment Station. This strain has almost entirely replaced the susceptible type in Texas. Double Dwarf Yellow milo No. 38 was developed in California (fig. 18, *B*) and has now replaced the susceptible strain (fig. 18, *A*) in California and Arizona. Resistant selections from Dwarf White milo and Heileman milo also have been made in California. Two resistant selections from Wheatland were developed in Texas. One of these is widely grown under the name of Martin's combine milo. Another resistant selection of Wheatland, called Westland, was developed and distributed in Kansas, where it now is widely grown. These three, together with the new varieties Caprock, Plainsman, and Resistant Beaver, which were developed in Texas, were grown on more than 3,000,000 acres in 1943 for harvesting with a combine.

Resistant selections from Sooner milo were distributed in Texas and Oklahoma. Resistant selections of darso, developed in Texas, Oklahoma, and Kansas, also are available, so that pythium root rot need no longer be a serious threat to the continued growth of these varieties.

The kafirs, feteritas, sorgos, broomcorn, and a number of the less common varieties or groups of sorghums are, on the whole, resistant to the disease and may be safely grown in soil known to be infested. The fungus may damage the root in these resistant varieties, but not enough to cause any measurable injury to the grain or forage. Extra Early Sumac is the only variety of sorgo known to be particularly susceptible, but a resistant strain is now available.

Crop rotation offers small hope for controlling pythium root rot because the causal fungus persists in the soil for several years.

Weak Neck

In some areas weak neck has become a serious farm problem since the introduction of combine harvesting of grain sorghums. The principal and most objectionable feature of weak neck is the breaking over of the peduncles, or upper part of the stalks, so that the heads fall to the ground and are missed by the combine (fig. 19).

Weak neck is the result of overripeness accompanied by an inherent weakness of the tissues in the rachis (the center stem of the head) and the peduncle (the upper part of the stalk), especially of the main stalk, of certain dwarf varieties of sorghum. Before the advent of the combine, grain sorghums usually were harvested soon after the grain was ripe and while the peduncle was still moist and rigid. At present, however, they often are combined long after the grain has matured and usually after a freeze, when the upper part of the stalk has lost its sap and the grain when threshed will be sufficiently dry for safe

storage (fig. 20). Under these conditions some dwarf combine varieties, many of which were developed from milo, frequently break over at the base of the peduncle, which by this time has become dry and spongy so that in wet weather it absorbs moisture readily, becomes limp, and is easily broken over by the wind and the weight of the head. The "boot" surrounding the base of the peduncle generally contains a slimy liquid composed of water and honeydew in which decay-produc-

FIGURE 18.—Pythium root rot of milo: *A*, Susceptible Double Dwarf milo; *B*, resistant selection of the same variety; both grown in infested soil.

ing bacteria and fungi develop. This liquid not only softens and weakens the peduncle but also harbors bacteria and fungi that can invade and rot the broken stalk, thus bringing about the final stage of weak neck.

FIGURE 19.—Weak neck in Colby milo, showing plants with the peduncles (upper part of stalks) broken over at the base. (Photographed by A. F. Swanson, Fort Hays (Kans.) Branch Agricultural Experiment Station.)

In very short plants, rotting of the peduncle is not always accompanied by breaking-over of the head, because the peduncle may be held up by the surrounding boot (fig. 21, *A*). Heads produced on secondary culms of such short plants, however, may break over because of the longer peduncle and consequent lack of a supporting boot (fig. 21, *B*). Some varieties, especially the sorgos, and to a large extent the kafirs, are less subject to weak neck, because in these varieties the upper stalks and central stems of the heads remain green and solid long after the seeds are ripe and dry.

Poorly developed heads with lightweight lusterless seeds sometimes are associated with the condition known as weak neck. This associa-

FIGURE 20.—Ripe heads of Early Kalo, showing two stages of dryness. *A*, Suitable for combine harvesting; seeds, rachises, and peduncles contain less than 11 percent moisture. *B*, Suitable for binder but not for combine harvesting; seeds contain 13.5 percent moisture, but rachises and peduncles still contain 30 to 33 percent.

tion, however, although frequent, does not always occur. Such heads may result from drought and extreme heat, when the seed is in the milk stage. This prevents proper filling and causes premature ripen-

FIGURE 21.—Weak neck in Colby milo: *A*, Primary culm with short, badly decayed peduncle supported by the enclosing boot; *B*, secondary culm with longer peduncle that will break over when it decays.

ing. Since these prematurely ripened culms are the first to go down with weak neck, it sometimes has been mistakenly assumed that the shriveled kernels are caused by weak neck.

Control measures.—Weak neck is largely a varietal characteristic. The remedy, therefore, apparently lies in growing or developing combine types of grain sorghum having stalks that remain green, as those of sorgo, for a considerable period after the grain is ripe. Two such varieties, Westland and Kalo Selection (H. C. 617), have been distributed recently. Another possibility of avoiding loss lies in the development of combine varieties having a stalk with a stiff rind that will support the head after the peduncle has dried out.

STALK ROTS [22]

Stalk rot, though doubtless present in the sorghum belt for a considerable time, had not been observed to cause serious, widespread damage until 1938, when severe lodging occurred in sorghum fields in Texas. Since then it has become increasingly important. At first, most of the stalk rot and lodging was attributed to the fungus causing charcoal rot, but now it appears that several other fungi also may be involved. Some of these, it is thought, invade the plant through openings caused by insects or by mechanical injuries. Probably bacteria also may invade the stalk and thus help bring about a water-soaked and later a rotted condition.

The symptoms of stalk rot may vary with the cause and location of the initial infection. If the upper stalk, or peduncle, is invaded by harmful fungi or bacteria, the injury usually is confined to the peduncle and rachis. In some varieties this may result in premature ripening of the head, drying of the rachis and peduncle, and a breaking over of the upper stalk as in typical weak neck, whereas the lower part of the stalk may remain healthy and the side branches that grow from the lower nodes may produce good heads. Infections in the lower part of the stalk, especially when they occur through wounds near the base of the stalk, usually are more destructive. External symptoms of such infections may at first consist of a water-soaked appearance of the stalk, with or without red or purple discoloration, or streaks on the surface of the stalk and in the veins of the sheaths and leaves. Later, one may observe poorly developed kernels, premature ripening, and frequently a softening at the base of the stalk, followed by lodging. The inside of the stalk may show water-soaked or discolored pith, or both, and a streaking of the vascular bundles or fibers. The inside of the roots of affected plants likewise usually appears water-soaked and discolored, and frequently the tips of the diseased roots are dead.

There are five fungi to which stalk rot has been attributed. While no one of these is definitely known to be the sole cause, each may play its part. The diseases believed to be caused by them are known as charcoal rot, spicaria stalk rot, anthracnose stalk rot, red rot, and rhizoctonia stalk rot. The stalk rots ascribed to each of these fungi are here discussed separately. Other organisms, including species of *Fusarium* and bacteria, undoubtedly contribute greatly to the general stalk rot complex. Stalk rot may follow a period of drought, extreme

[22] Prepared with the assistance of E. C. Tullis, pathologist, Division of Cereal Crops and Diseases.

heat, or other unfavorable conditions that weaken the plant. The disease is favored also by injuries to the stem, crown, or roots caused by cultivation implements, insects, wind, and hail, or any other agency that makes an opening for the entrance of destructive fungi and bacteria.

Control measures.—Definite methods for the control of these five stalk rots are not yet known, though resistant varieties offer the principal hope for reducing losses caused by them. Varieties that appear to be resistant are mentioned in the discussions of charcoal rot (p. 37), and anthracnose leaf spot (p. 11). Little is known concerning resistance to the other stalk rots. Rotation and certain other cultural practices may prove helpful, as will also the control of insects that attack the stalks of sorghum plants and leave openings through which stalk rot fungi gain ready entrance.

Charcoal Rot

Since 1938, charcoal rot [23] has resulted in serious losses in fields of sorghum throughout Texas, Oklahoma, Kansas, Nebraska, and New Mexico. It occurs also in California, Illinois, Indiana, Maryland, and, doubtless, in other States. It is more or less sporadic in its appearance, being associated perhaps with crop sequence in addition to certain soil and weather conditions that subject the crop to a period of stress, such as extreme heat, drought, or other injury at a critical stage of development. It is likely to occur in dry spots in a field, such as terrace crowns, knolls, or areas underlain by coarse sand or gravel.

Injury due to charcoal rot usually does not become evident until the sorghum plants approach maturity. Close examination at that time reveals many poorly filled heads with lightweight kernels, a premature ripening and drying of entire stalks, and the presence of lodged stalks. Further examination shows that many stalks are soft and discolored at the base, with the pith at this point disintegrated and the separated vascular fibers in the stalks presenting a shredded appearance (fig. 22).

An abundant moldlike growth of a pink or white *Fusarium* fungus frequently is found at this stage and probably, along with bacteria usually present, assists in the destruction of the stalk. Soon thereafter, the affected stalks usually break over at the base (fig. 23, *A*). If a period of dry, warm weather follows this stage of the disease, the strands or vascular fibers in the interior of the stalks become covered with small black bodies visible to the naked eye (fig. 22). These are compact masses of mycelium, known as sclerotia, formed by the fungus causing the disease. The sclerotia may be found up to the third or even the fourth internode, or joint, and also in the crown and the main roots.

When the roots and lower parts of the stalks decay in the field, the sclerotia become incorporated with the soil. Here, under proper conditions of temperature and moisture, they germinate by sending out strands of mycelium, which may infect the roots of any one of more than 20 different kinds of crops. Among these are corn, red clover, lespedeza, cotton, sugar beets, sweetpotatoes, sunflowers, cowpeas, soybeans, and several species and varieties of peas and beans.

There seems to be some varietal resistance to charcoal rot and this offers the principal hope of control. The milos and milo derivatives suffer the greatest damage; feterita, hegari, and Sudan grass are less

[23] Caused by *Macrophomina phaseoli* (Maub.) Ashby (=*Sclerotium bataticola* Taub.

seriously affected; while most varieties of kafir and sorgo are rather resistant. Under severe conditions, however, even the more resistant varieties are damaged. There is some evidence that the disease is more severe where stands are light than where they are heavy (fig. 23).

FIGURE 22.—Charcoal rot of sorghum: Diseased stalks, showing shredding of interior by the fungus *Sclerotium bataticola*. Numerous tiny black fruiting bodies (sclerotia) occur on the vascular bundles.

Spicaria Stalk Rot

Another fungus [24] found associated with stalk rot in the northern part of Texas produces symptoms nearly the same as those of charcoal rot. Instead, however, of small black sclerotia visible to the naked eye, this fungus produces within the dried rotted stalk a powdery mass of white spores that can be seen individually only with the aid of a microscope. The fungus apparently invades the sorghum plant only through openings made by insects, mechanical injuries, or other agen-

FIGURE 23.—Charcoal rot in field of Wheatland milo: *A*, Severe where stand is poor; *B*, less severe where stand is good. (Photographed by A. F. Swanson, Fort Hays (Kans.) Branch Agricultural Experiment Station.)

cies. Indications are that it grows more rapidly than the charcoal rot fungus after it once gets into the stalk and soon causes it to break over at the base.

Some varieties seem less susceptible than others to this fungus, but further testing is advisable before definite statements on varietal reaction can be made.

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[24] *Spicaria elegans* var. *sorghina* Sacc.

Anthracnose Stalk Rot of Broomcorn and Red Rot of Sorgo

Anthracnose stalk rot [25] severely injured broomcorn in some sections of Illinois in 1941 and 1942 (fig. 24), impairing head development and causing the plants to lodge before maturity. Injury from this disease has been reported also from several other States. The fungus apparently invades the crown of the plant at the junction of the root with the stalk and spreads up the inside of the stalk, growing in the conducting tubes and vessels and thus interrupting the movement of water and food materials needed by the plant. The diseased areas turn red, and the lower part of the stem becomes soft and spongy. The upper part of the stalk dries prematurely, and frequently the stalk breaks over near the ground (fig. 24). By this time, reddish-brown

FIGURE 24.—Broomcorn in Illinois ruined by anthracnose stalk rot. (Courtesy of B. Koehler, Illinois Agricultural Experiment Station.)

streaks or blotches may be found on the surface of the stalk. The center of these blotches is gray and bears the spores or reproductive bodies of the fungus growing out from the inside of the stalk. The area of discoloration and decay in the interior may be confined to the lower part, or it may extend up the entire length of the stalk (fig. 25). The fungus is carried over from one year to the next on the seed and on dead plant material in or on the soil.

Red rot [26] of sorgo was damaging in some sections of Mississippi in 1940 and 1943, particularly where early growing conditions were favorable but were succeeded by drought during maturity (fig. 26).

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[25] Caused by the leaf spot fungus *Colletotrichum graminicolum* (Ces.) G. W. Wils.

[26] Caused by a species of fungus identical with or closely related to *C. graminicolum* or *C. falcatum* Went. The discussion and illustrations of the red rot disease of sorgo were contributed by M. L. Lohman, assistant pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering.

FIGURE 25.—Anthracnose stalk rot in broomcorn. Interiors of three stalks at left show discoloration and decay caused by the fungus; sound stalk at right. (Courtesy of B. Koehler, Illinois Agricultural Experiment Station.)

Red rot causes stems of sorgo to break over at about maturity, often before they are suitable for harvest. It lowers the quality of the juice and also reduces the yield of sirup. The disease is most injurious to varieties that require a long growing period but injures also the earlier varieties if harvesting is delayed.

The red rot fungus apparently enters directly through the rind in the lower part of the internodes and peduncle, and the rot usually spreads upward from the point of infection. Diseased stems frequently break over at about the middle, or four or five joints above the ground. Diseased but unbroken stalks often may bear heads with abnormally small seeds. The lesions on the outside of the stalks are dark-colored when exposed to sunlight during development and salmon-colored when produced in rainy periods or under the leaf sheaths (fig. 27).

When the infected stalks are split, the pith is seen to be discolored red or purplish red in most varieties and yellowish or orange in Leoti. Usually there are lighter colored, mottled areas or bars running crosswise. These bars, sometimes appearing only as lens-shaped areas in the rind, usually are associated with the discolored lesions caused by the red rot fungus. Infection has not been observed in the lower internodes, crown, or roots. The fungus probably overwinters in the litter of sorgo and Johnson grass.

Sumac, White African, and Early Folger have shown some degree of resistance to red rot, but Honey, Hodo, and Sugar Drip are highly susceptible. Certain other varieties appear to be intermediate in resistance.

FIGURE 26.—Rex sorgo in Mississippi seriously damaged by red rot at harvesttime.

Rhizoctonia Stalk Rot

A soil-borne fungus [27] that attacks potatoes, cotton, and several other crops has been identified also as the cause of a stalk rot of sorghum in northern Texas. This stalk rot differs from charcoal rot in that it first attacks the pith and produces in it a reddish discoloration, while the fibers remain as light streaks in the discolored pith. Later, sclerotia of the fungus may be found on the outside, under the leaf sheath. These sclerotia, differing from those of the charcoal rot fungus, are brown instead of black and are somewhat larger; also, they are on the outside of the stalk instead of inside.

[27] *Rhizoctonia solani* Kuehn.

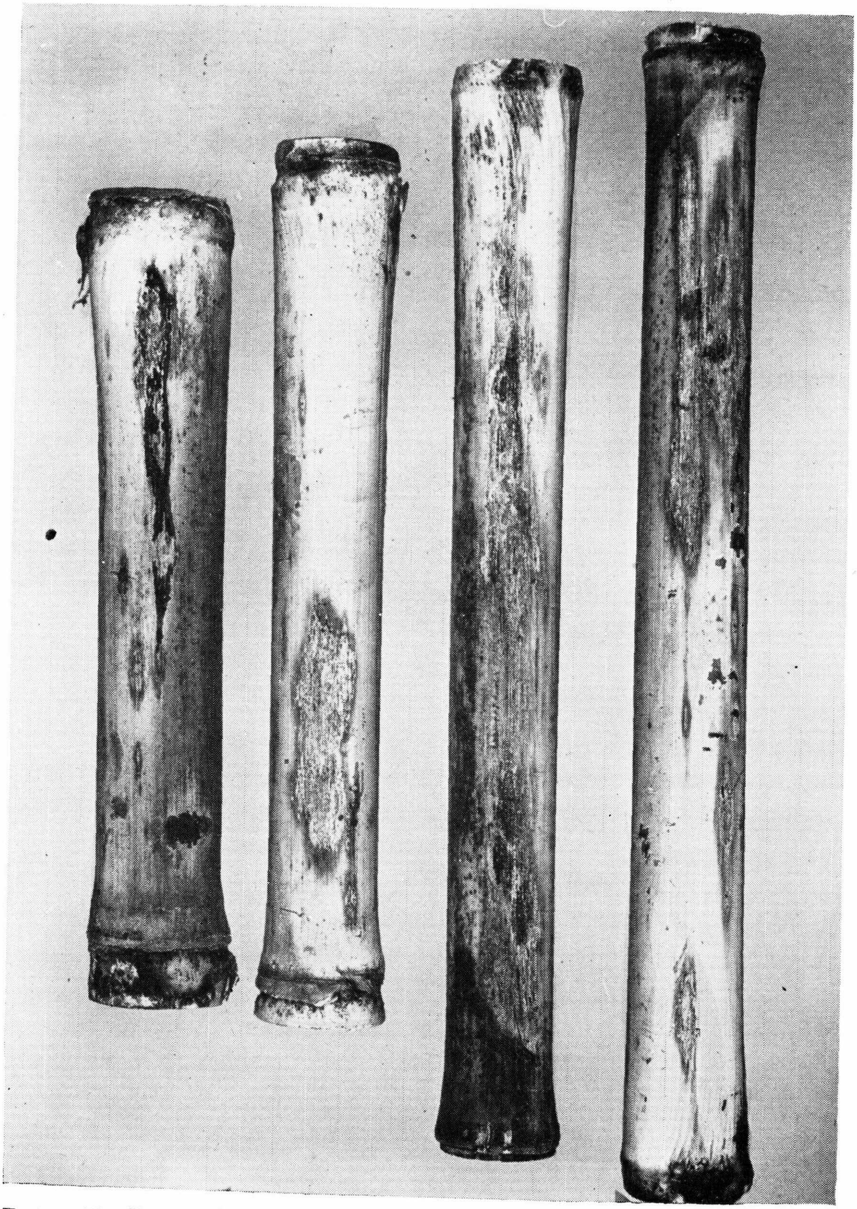

FIGURE 27.—Red rot in sorgo, showing lesions bearing numerous fruiting bodies of the causal fungus.

SEED TREATMENT

The treatment of sorghum seed with an effective dust fungicide is a cheap form of crop insurance and should be practiced every year. Sorghums are of tropical origin, and therefore the seeds germinate best at a temperature considerably higher than the soil temperatures that

usually prevail at planting time in the United States. This exposes the seeds to the attack of various seed-borne and soil-borne fungi. These fungi, which may rot the seed or kill the seedling, can be combated to a great extent by treating the seed with an effective dust fungicide, of which there are several on the market. These fungicides also control the two kernel smuts and prevent the spread of

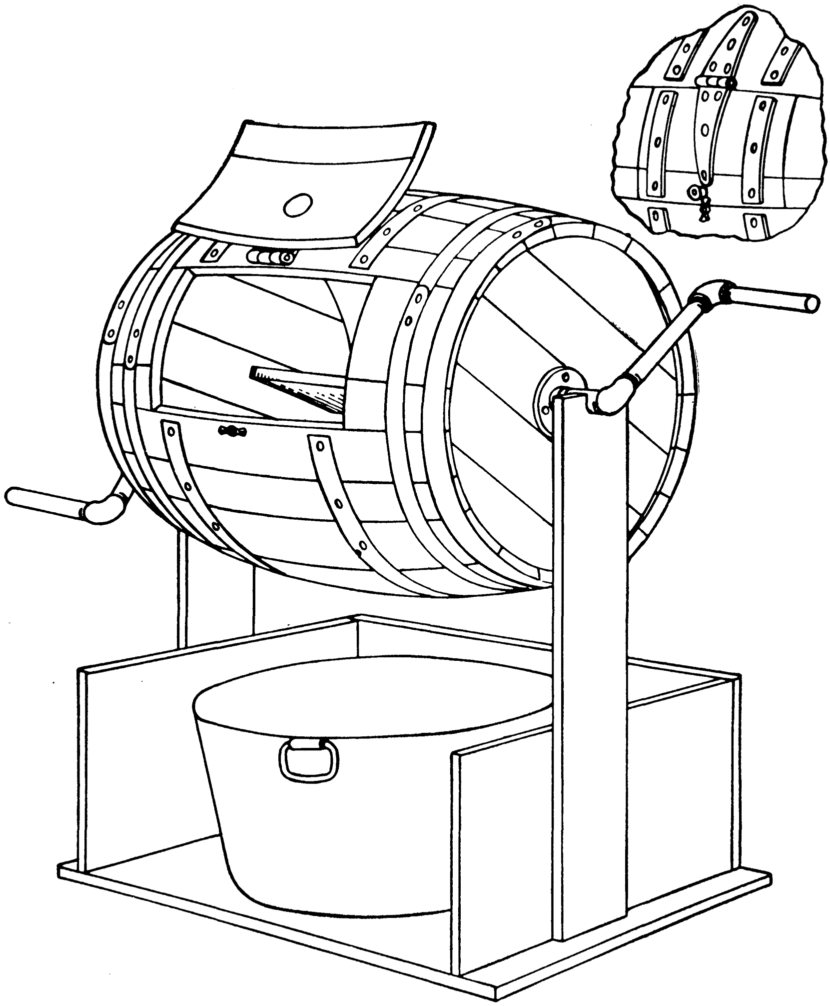

FIGURE 28.—Barrel mixer for treating sorghum seed with dust fungicides. (Designed by F. W. Oldenberg, University of Maryland.)

head smut to the soil of other fields by means of spores on the seed. While seed treatments cannot be depended upon to prevent bacterial and fungus leaf diseases, it may delay the spread of some of them to new areas. Treatment of sufficient seed for most farms is economical both in chemicals and in labor, because only 2 to 5 pounds is usually required to plant 1 acre. This quantity can be treated at a cost of 1/4

to 1 cent for material. Since seed treatment, in addition to controlling smuts, also may control other diseases and generally improves stands, it is advisable to treat all sorghum seed every year even though the seed may be absolutely free from smut and planting conditions may be ideal for quick germination and early growth.

Seed treatments are of two general classes: (1) Dust treatments, applied by thoroughly mixing with the seed the proper quantity of some specially prepared finely divided chemical dust, so as to coat the seed thoroughly with a thin film of the fungicide; and (2) liquid treatments, applied by soaking the seed in a solution of formaldehyde or similar preparation.

At present only dust treatments are recommended for sorghum. Liquid treatments should be used only when materials suitable for dusting the seed cannot be obtained.

DUST TREATMENTS

The dust fungicides now available for treating sorghum seed may be classed as either metallic or nonmetallic. The chief metallic fungicides are copper carbonate, basic copper sulfate, and New Improved Ceresan (ethyl mercury phosphate). The principal nonmetallic materials that may be used are Arasan, Spergon, and sulfur.

Copper carbonate.—Copper carbonate dust for seed treatment comes in two grades, one containing about 50 percent copper and the other 18 to 25 percent. The higher grade, which is to be preferred, should be applied at the rate of 2 or 3 ounces per bushel; the lower grade at twice that rate. The dust should be thoroughly mixed with the seed in a treater made for that purpose (fig. 28), or if no such treater is available, the mixing may be done in an old milk can, churn, or any other dusttight container. For a small quantity of seed, a lard can or any similar container with a tightly fitting cover may be used. The mixing must be thorough, so that every kernel is coated with a film of dust. There is no danger of seed injury due to overdosage, and the treated seed may be stored indefinitely. Meanwhile, the dust protects the seed from insects and rodents.

Basic copper sulfate.—Basic copper sulfate dust is a blue-green powder containing about 50 percent copper. It is sold under various trade names, as Acme Smutreat, Acme Kopper King, Basul, Lucas,

CAUTION

Copper carbonate and basic copper sulfate are poisonous and may cause extreme nausea and vomiting if inhaled or swallowed. Therefore, an effective dust mask or respirator should be worn over the nose and mouth when applying these dusts or when handling treated seed, even when the work is done in the open air. Sacks that contained treated seed should be thoroughly cleaned before being used for grain that is to be fed. Treated seed should not be used for feed or mixed with untreated seed that is to be so used.

Cappatone, and Tennessee tri-basic copper sulfate. It should be applied in the same way as copper carbonate, and all other statements made about the use of that preparation apply also to this. Both of them control kernel smuts and also improve emergence and stand by combating harmful fungi in the soil.

New Improved Ceresan.—New Improved Ceresan contains 5 percent of the somewhat volatile chemical ethyl mercury phosphate and should be applied to the seed at the rate of not more than one-half ounce per bushel. Certain precautions are advisable in using it on sorghum seed, in order to avoid seed injury. The seed should be well dried, so that it is of low moisture content, as the presence of much moisture in the seed causes it to be injured by this dust, especially if it is stored after being treated. The recommended rate of one-half ounce per bushel should be carefully observed. Some varieties of sorghum are more susceptible to seed injury by this chemical than others, but in the absence of more complete information on varietal behavior, seed of all varieties should be treated with equal care. The dust, carefully weighed or measured, should be applied to a weighed quantity of seed and the two mixed in a treating machine, as described for copper carbonate. The seed and dust also may be mixed by shoveling over several times on a clean floor until no streaks of dust are visible. The mixing need not be so thorough as in the case of copper carbonate and other nonvolatile dusts. After treatment, the seed should be put into a cloth sack and allowed to stand in a dry place for not less than 1 nor more than 3 days before planting.

CAUTION

New Improved Ceresan is poisonous, and reasonable care should be taken to avoid breathing the dust or its fumes or having it come in contact with the skin, especially if the skin is moist, as it will cause blisters. The treating should be done in the open air or in a well-ventilated place. If dust is present in the air, a dust mask should be worn over the nose and mouth. The sleeves should be rolled down, and gloves may be used to cover the hands and wrists. Treated seed should not be used for feed or food.

Arasan.—Arasan, a recently developed fungicide containing 50 percent tetramethylthiuramdisulfide, was at first recommended chiefly for peanuts and vegetables, but was found excellent also for corn and sorghum. It effectively controls the kernel smuts of sorghum and greatly improves emergence and stand when soil conditions after planting are unfavorable for germination and growth. It should be applied at the rate of 1 to 2 ounces per bushel in the same manner and with the same thoroughness and precautions described for copper carbonate. It does not injure sorghum seed even though the seed is treated several months before planting.

Arasan is relatively nonpoisonous to farm animals and human beings, but persons who are allergic to sulfur may develop slight skin irritations from excessive exposure to it.

Spergon.—Spergon, a fungicide containing 98 percent tetrachloroparabenzoquinone, was developed principally for vegetable seed treatment, but also controls the kernel smuts of sorghum and, to some extent, improves emergence. It should be applied at the rate of 1 to 2 ounces per bushel in the same way as copper carbonate, and the same precautions should be taken even though Spergon is not highly poisonous.

Sulfur dusts.—Flowers of sulfur and various forms of sulfur dust, if sufficiently fine to stick to the seed, are fairly effective in controlling the kernel smuts of sorghum when applied at the rate of not less than 2 ounces per bushel. They are not effective, however, against the soil fungi that cause seed rot, damping-off, and seedling blight and, in some cases, have even reduced emergence. The sulfur dusts have the advantage, however, of being abundantly available, cheap, and nonpoisonous. With good seed and warm soil, they are fairly good substitutes for other seed disinfectants for smut control. They are applied in the same manner and with the same precautions described for copper carbonate. Sulfur dusts should not be inhaled, as some persons are allergic to this chemical.

LIQUID TREATMENT

Formaldehyde formerly was employed to some extent for the control of the sorghum kernel smuts, but is now seldom used. The formaldehyde treatment is very effective in preventing seed-borne diseases but has no effect on those caused by soil-borne fungi. It rarely improves emergence but, on the contrary, frequently injures the seed. In general, good dust treatments are preferable, but if they are not available and seed treatment is highly desirable because only smut-infested seed is available, formaldehyde may be used as follows:

Mix 1 pint of commercial formaldehyde (containing 37 percent formaldehyde by weight) with 30 gallons of water in a tub or other convenient container. If only a small quantity of seed is to be treated, a proportionately smaller quantity of the solution may be prepared, care being taken to use 1 part of formaldehyde to 240 parts of water. The seed should first be thoroughly cleaned and then placed in a loosely woven burlap bag, half-filled and tied at the top. Immerse the half-filled sack of seed in the formaldehyde solution for half an hour, lift it out, and let it drain a few minutes; then spread the seed in a thin layer on a clean floor or canvas in a well-aired place to dry. Stir it occasionally to hasten drying and plant as soon as it is dry enough to feed through the planter. To avoid seed injury, it is best to treat the seed on the same day it is to be planted. Treated seed, however, *should not be planted in dry soil.*

CAUTION

Formaldehyde is poisonous. Keep it out of the eyes and do not breathe the fumes!

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